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NOTES

ON THE

CLIMATE AND METEOROLOGY

OF

DEATH VALLEY, CALIFORNIA.

BY

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CHIEF OF WEATHER BUREAU.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
WEATHER BUREAU,
Washington, D. C., May 24, 1892.

SIR: I have the honor to submit herewith for publication Weather Bureau Bulletin No. 1, Notes on the Climate and Meteorology of Death Valley, California.

Very respectfully,

MARK W. HARRINGTON,
Chief of Weather Bureau.

HON. J. M. RUSK,
Secretary of Agriculture.

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NOTES ON THE CLIMATE OF DEATH VALLEY, CALIFORNIA.

I.—PHYSICAL FEATURES OF THE VALLEY.

The southwestern corner of the arid region of the west is occupied by the Colorado and Mohave deserts, the latter the northern and more extensive of the two. The northern margin of the Mohave Desert reaches out into narrow valleys lying between bold ridges of mountains which run nearly north and south. These valleys are usually shallow, but a few are characterized by great depth. The most remarkable of these is Death Valley, in that its bottom is said to descend below sea-level, while it is about 200 miles from the coast, and between it and the latter intervenes the lofty Sierra Nevada Mountains. This valley is said to owe its name to the melancholy fate of a party of immigrants, who, about 1850, perished from thirst within its limits.

Death Valley lies between the brilliantly colored Funeral and Amargosa ranges of mountains, reaching an elevation of 5,000 to 6,000 feet on the east, and the Panamint Mountains on the west. The latter reach an elevation of 8,000 or 9,000 feet, and culminate opposite the middle of the lower valley in Telescope Peak said to be 10,938 feet high. The valley is an independent drainage basin, nearly closed in on the south by a rapidly-rising ridge about 2,000 feet high. The southern part, into which pours the catch of the entire basin and that of the higher Amargosa Valley on the east, is nearly level, and it is to this portion that the name, Death Valley, is applied. The gradually rising northern or northwestern arm is 50 or more miles in length. It is mapped as "Lost Valley," but is usually known as "Mesquite Valley," under which name the meteorological observer refers to it in his notes. Death Valley proper lies between latitudes 35° 40′ and 36° 35′ north, and longitudes 116° 15′ and 117° 5′ west from Greenwich. It is directly east of Tulare and Owens lakes, about 50 miles from the latter, and the boundary between Nevada and California runs not far east of its eastern margin. It is about 75 miles long, with an axis running nearly north-northwest and south-southeast. The width from crest to crest is from 20 to 25 miles, but the bottom is only 12 or 15 miles wide at its widest point; opposite the meteorological station it was about 6 miles wide.

The first visit to this valley by scientific observers seems to have been made in 1861 by a party of the California and United States Boundary Commission, in charge of Dr. Owen. In the summer and early autumn of 1875 one of Wheeler's surveying parties, under

Lieutenant R. Birnie, jr., crossed it several times and camped some days within it. A brief account of these visits is given in Wheeler's annual report for 1876, pages 132 and 133. Wheeler's surveys were later reduced to a series of "Atlas sheets," on number 65[D] of which may be found a map of Death Valley. A copy of the eastern half of this, enlarged by photography to a scale of 4 miles to the inch, was kindly furnished by Mr. Henry Gannett of the Geological Survey.

In 1891 an exploration of the valley was made under the direction of Dr. C. Hart Merriam, with the co-operation of the Geological Survey and the Signal Service, continued by the Weather Bureau. The present paper is the meteorological contribution to the results of this exploration.

A correct interpretation of the meteorological phenomena requires some knowledge of the physical features of the valley. The following notes on this point have been in part gleaned from Birnie's and Wheeler's reports and Cronise's "Natural Wealth of California," and in part from manuscript notes of the meteorological observers in Death Valley and at Keeler. The valley proper is probably the bed of a former lake of bitter water. Along the east side runs a long, narrow, glistening white artery of salt, with borax deposits in three or four places sloping down to it. The crust is usually very thin, breaking through under the feet of the traveler; but in one place it is strong enough to hold up, without breaking, the roadway that crosses it. Some portions of the valley bottom near a salt marsh at the northern end are covered with white, shifting sand, or an ash-like earth mixed with a tenacious clay. When wet it is very soft, and can be traversed only with great difficulty, and only when dry is it possible to cross with horses.

The Amargosa River, a stream of great length but very small volume, comes into the valley at the southern end. It rises in Nevada, and passing through the shallow valley, to which it gives its name, just east of the Funeral range, it flows around the southern end of this range. It is about 100 miles long, but is generally dry in some parts of its course, and is nearly always dry where it enters Death Valley.

Furnace Creek flows into Death Valley near the northeastern angle from a cañon of the Funeral Mountains. Its waters are derived from numerous warm springs that rise on the north side of the cañon, a mile above its mouth. The warmest of these have a temperature of about 90° F. [Birnie]. The cañon is 10 or 15 miles in length, but the stream is only about 2 miles long, and the water sinks before reaching the bottom of the valley. The water is the best for drinking and domestic use, though by no means cool. From the north a stream is said to flow in from Mesquite Valley, which gives a quantity of bitter water.

There are also a few springs along the west side of the valley. In wet seasons there must be much drainage from the mountain slopes and from the valley to the north.

Water is probably often present here on the surface during some

seasons and there is no reason why a temporary lake may not exist at times. Such a lake has been occasionally reported, and Birnie found fresh and clean layers of salt with distinct ripple-marks. In dry seasons there is no water on the surface, but it can be found almost anywhere by digging down a few feet. The water appears, however, to be always somewhat unwholesome and it is generally so bitter and saline as to be entirely undrinkable by man or beast.

The salt marsh at the bottom of the valley is destitute of vegetation, but is bordered on the west by numerous clumps of mesquite. It is encircled by a slope a mile or two wide on the east side and 6 to 10 miles on the west side, running up to the mountains, and sparsely covered with several species of desert shrubs and cacti, interspersed with tufts of bunch grass. This slope is crossed by numerous gullies, generally dry. At the northern end of the valley is a salt marsh covered with a tall, coarse grass. The sand is here bare and white, but over it are scattered a few clumps of mesquite, from around which the wind has carried the sand away until they are perched upon hillocks, 15 or 20 feet high [Birnie].

The animal forms noted by the observer, or already recorded, in summer are few. Horned toads, lizards, and snakes are the most conspicuous forms of animal life, while Cronise mentions a small black gnat which, swarming in myriads during the spring, greatly annoys the traveler by entering his eyes, ears, and nose. On September 1 the observer noted a large flock of blackbirds which made their appearance near Furnace Creek.

The valley has been often visited by prospectors who have made prolonged stays there in search of its reputed mineral wealth. One man is reported to have kept cattle on the mountain side for a year or more. About a mile northwest of the mouth of Furnace Creek, on the east side of the valley, is what the Pacific Coast Borax Company, owners of the property, call "Greenland Ranch." About 30 acres are fenced in and water is brought from Furnace Creek for irrigation and stored in two small reservoirs. The plot is very productive, yielding six or seven crops of alfalfa per year. A few cottonwoods and fig trees are grown by aid of constant irrigation. The fruit of the fig tree matures early, and, though small, is of good quality.

The feature of greatest interest about Death Valley is its reputation for extending below sea-level. The observations on which this conclusion is based seem to be all barometric, and have apparently never been published. Lieutenant Birnie says (Report, 1876, p. 132) that his first station in the valley was a few feet below sea-level. This was at Bennetts Wells on the west side. He afterwards found that there was a considerable space in the bottom of the valley which was about 100 feet below sea-level. In Lieutenant Marshall's report on the "Results in Barometric Hypsometry" (Wheeler's Geo. Surveys, Vol. II, p. 558) are given six stations in Death Valley with altitudes of —69.2, +57.1,

+7.3, —45.3, —62.4, —110.0, and —63.9 feet, where the negative sign indicates below, and the positive above, sea-level. These stations are not described in the text, but are given on the map sheet 65[D]. Williamson, in his book "On the Use of the Barometer in Surveys and Reconnoissances," says (page XXV) that Death Valley is "estimated from reliable barometric observations to be 175 feet below the level of the sea." The exploration of 1891 included work by a topographer, and his results will undoubtedly give greater consistency and exactness to questions of the elevation or depression of the valley. In the meantime it should be noted that barometric observations are an unsatisfactory expedient for determining elevations under the most favorable circumstances. In this case they are rendered still more unsatisfactory by peculiarities of pressure, which will appear later in this paper, due to the physical peculiarities of the valley.

II.—THE STATION AND INSTRUMENTS.

The meteorological station was established on April 30, 1891, and the observations continued without a break until the end of the next September, a period of five months during the hottest part of the year. The station was in a building at the borax works known as "Coleman," owned by the Pacific Coast Borax Company, on the east side of and near the northern end of Death Valley proper; it was situated at the foot of the Funeral Mountains, about two miles northwest of the mouth of Furnace Creek, in approximate latitude 36° 28′ north, longitude 116° 51′ west from Greenwich. The correction for 75th meridian time is 2h. 47m. The soil at the station was a white, shifting sand, destitute of vegetation except for an occasional mesquite bush. The observer in charge was Mr. John H. Clery, who deserves great credit for the success with which he carried on the observations under the most trying circumstances. Mr. R. H. Williams was the assistant, but he succumbed to the heat soon after his arrival and had to return to Keeler for treatment.

The account of the instruments which follows is due to Professor C. F. Marvin, in charge of the instrument room, Weather Bureau.

The instruments furnished to the station were, in most respects, the typical and standard instruments supplied to the regular second order stations of the Bureau, with the addition of a barograph and thermograph.

Owing to the difficulties of transportation to the station, special arrangements were made in several particulars to render the equipment as portable as possible, but at the same time providing everything necessary to a fully equipped station.

The following table gives the complete list of instruments and their elevation, so far as known:

Instruments at Furnace Creek (Death Valley), California.

Instrument.	Maker.	No.	Elevation.
Anemograph, U. S. Weather Bureau pattern— Robinson anemometer	J. P. Friez	680	2 feet 7 inches above apex of roof; 22.6 feet above ground.
Anemometer register	Hahl & Co	111	
Barograph	Richard Bros	6661	
Barometer, mercurial	H. J. Green	349	2 feet 6 inches above door sill.
Barometer, aneroid (used in monthly comparative readings only).	P. H. B. Naudet.	13	
Compass			
Rain gauge, standard, 8-inch collector		1344	3 feet above ground.
Shelter, standard pattern			Floor 5 feet above ground.
Thermograph	Richard Bros	8981	
Thermometer—			
Mercurial (dry bulb)	H. J. Green	3426	5 feet 10 inches above ground.
Mercurial (wet bulb)	do	3431	
Maximum	do	2761	6 feet above ground.
Maximum (extra, not used)	do	2762	
Minimum, alcohol	do	2197	6 feet above ground.
Minimum, alcohol (extra, not used)	do	2545	
Whirling psychrometer—			
Small size. { Wet bulb thermometer No. 2734; Dry bulb thermometer No. 2758 }	Schneider Bros.	47	
Special. { Wet bulb thermometer No. 3427; Dry bulb thermometer No. 3430 }	Schneider Bros.	37	
Wind vane, special (see text)			

Fig. 1 shows the general arrangement of the instruments in and about the office, as given by report of the observer.

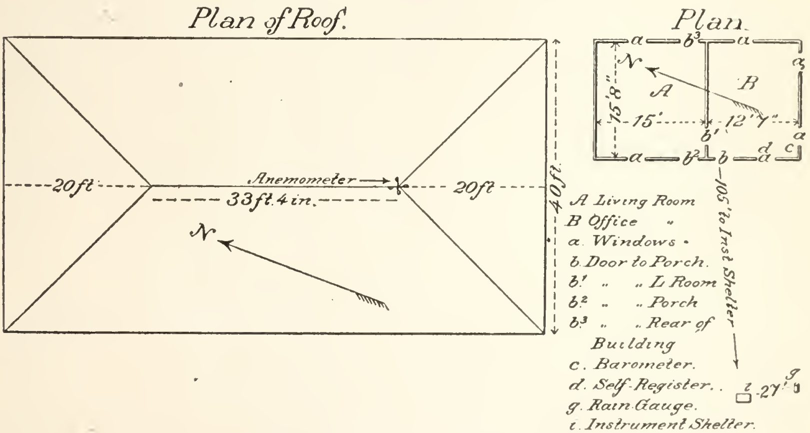

FIG. 1.

A brief discussion of further details respecting the instruments, their errors, etc., is given as follows:

ANEMOGRAPH.

The anemograph is more properly discussed in its separate parts, namely, the anemometer and the anemometer register.

Anemometer.—The anemometer used in measurement of wind movements was of the Robinson type and regular Weather Bureau pattern.

The construction of these instruments is carried to a very high degree of mechanical perfection under the rigid scrutiny of the Bureau, and the observations made at Furnace Creek are considered most satisfactory. The dimensions and important characteristics of the anemometer are repeated here for the convenience of those who may wish to know them.

The four hemispherical cups are each 4 inches in diameter, and are attached to slender, square, steel arms in such a way that the cup centers are each 6.72 inches from the axis of revolution. In accordance with Robinson's original assumption that the travel of the centers of the cups is one-third the wind movement, the above anemometer cups will revolve 500 times per mile of wind, and the ingenious and relatively almost frictionless dial mechanisms are constructed and graduated upon this basis of 500 revolutions to the mile of wind movement.

Provision is made by which the anemometer closes an electric circuit once for each 500 revolutions of the cups; that is, nominally, for each mile of wind movement. This closure of the electric circuit is the means employed to secure the continuous record of the wind movement by means of the anemometer register.

Gibbon's register.—This apparatus consists of a chronograph cylinder whose circumference is just 12 inches and revolved by clock work at the rate of 4 revolutions in 24 hours; that is, 2 inches per hour. In addition to this movement of rotation the cylinder is also made to move endwise about $\frac{1}{4}$ inch for each revolution. An electro-magnet, the armature of which carries a pencil, is so arranged that the latter may be made to trace a continuous spiral line upon the sheet of paper wound upon the cylinder. When the register is placed in electrical communication with the anemometer, the closure of the circuit in the latter causes the pencil to trace a short mark across the spiral line above described. These cross marks are made for each 500 revolutions of the anemometer cups; that is, nominally, for each mile of wind.

By an ingenious construction of the contact mechanisms in the anemometer one contact in every ten is prolonged during an entire mile of wind movement, making it conspicuous on the record, thereby facilitating the counting of the record and at the same time affording an excellent check against any loss of record from weak batteries and similar contingencies.

From the diagram above it is seen the anemometer was exposed nearly 3 feet above the apex of the roof of the building, at a height of 22.6 feet above the ground.

BAROGRAPH.

The aneroid barograph was of the usual type constructed by the Richard Bros., of Paris. In this instrument eight of the corrugated metallic cells so commonly used in aneroids are joined together so that

their united movement with change of pressure acting through properly arranged levers imparts a greatly magnified movement to a delicate recording pen tracing its movement upon the revolving sheet of paper. A pen movement of one inch is thus made to represent a change of one inch in barometric pressure, and the sheet is ruled to spaces of $\frac{1}{20}$ inch; that is, .05 inch of barometric pressure. Owing to the thickness of lines, etc., the error of a pressure reading from the record sheet is, however, probably greater than $\pm$.01 inch. The time movement of the sheet of paper is comparatively slow, being only about 1.6 inches in 24 hours, or about $\frac{1}{15}$ inch per hour. Less than a half hour is, therefore, scarcely discernable, and as the sheet is ruled with lines only for every two hours and as further uncertainty arises from the fact that the clock movements used by Richard Bros. rarely keep very good time, it is impossible to secure very great accuracy from this instrument, even supposing the aneroid mechanisms to be perfectly reliable. As is well known, however, these are never found to keep in close accord with the standard pressure instruments, so that, at best, the barograph is but a differential instrument, whose ever changing corrections for instrumental error must be determined by frequent comparisons with standards. Very similar difficulties arise in the case of the thermograph, and the expedients resorted to in the practice of this Bureau for eliminating errors from these causes will be described further under the thermograph.

It is frequently found that the barographs are but indifferently compensated for temperature, thus giving rise to additional errors. The particular instrument used at Furnace Creek has, however, been carefully tested in this respect and is found to be almost insensible to considerable temperature changes.

BAROMETERS.

Aneroid barometer No. 13.—This instrument was one of the best of its kind, but was furnished only as a last resort in case of failure of the mercurial barometer. Comparative readings were taken between this and the mercurial barometer at the end of each month while the station was in operation.

Mercurial barometer No. 349.—Each regular station is kept supplied always with two good mercurial barometers, but in the present instance only one was furnished, not only because of the temporary character of the station, but as well from the difficulty of safely transporting the instruments from Keeler, Cal., the nearest point of supply. A newly filled and adjusted barometer was sent out from this office for the station at Furnace Creek, but it did not survive the long journey across the continent, and when examined at Keeler and compared with the station instruments was found to be unserviceable. Instructions providing for such a contingency directed the observer to take the "extra" barometer from Keeler. This barometer was No. 349, a comparatively

old instrument, having been in service at Keeler since January, 1885, but in every respect reliable. The scale of this barometer was subdivided to tenths of inches and provided with a vernier reading to .01 inch; estimations to less than .005 being easily made. The barometer tube was approximately $\frac{1}{4}$ inch in diameter inside, and the construction of the cistern of the regular well-known Fortin type, the mercury in the cistern being adjusted by screw motion to the level of a fixed ivory point.

The correction for instrumental error, including capillary action, was determined by comparison with standards at this office in January, 1885; this correction was +.006 inch.

The temperature of the mercury and scale was taken from the readings of an attached thermometer secured at about the middle point of the tube. This thermometer was not stem-graduated, and the readings could not readily be made to less than whole degrees. When the barometer was returned to this office after the station was closed, a comparison of the attached thermometer with standards showed its corrections to be less than one-half degree, so that possible errors from this source are entirely insignificant.

By a peculiar circumstance of seeming inattention a considerable length of detached thread of mercury remained unnoticed in the top of the attached thermometer, the temperature readings being thereby highly erroneous. This state of affairs was not discovered until the evening of June 15, 1891. During the following day the observer took twenty-five comparative readings, at intervals of one-half hour, with another thermometer suspended near the barometer. The detached column was then united and the next day similar readings were taken, in which the two thermometers gave practically the same temperature. From these comparisons the error of the attached thermometer was found to be a fraction over 26°.

The corresponding error in the barometric pressure was very nearly .07 inch, and instructions were given to correct the back records accordingly, including all records made up from the barograph. The barometer, after over two and one-half years' service at Keeler, was compared in August, 1887, with an inspector's barometer by Lieutenant Maxfield, and found to be in excellent condition, differing by only .002 inch from the readings of his instrument.

Regular monthly comparisons between the two barometers at Keeler showed no deterioration in this instrument. The final series of comparative readings made between the two barometers upon the return of No. 349 to Keeler, after the station at Furnace Creek had been closed, still show No. 349 to have undergone no sensible change in its instrumental error. The comparative readings made during 1891 between barometers No. 349 and No. 509, the station instrument at Keeler, are given in the following table:

Summary of comparison of barometers Nos. 349 and 509, at Keeler, Cal.

Date. 1891.	Corrected means.*		Differences.	Remarks.
	No. 509.	No. 349.		
	Inches.	*Inches.*	*Inch.*	
January 31 ..	26.202	26.203	.001	Made at Keeler before opening station at Furnace Creek.
February 28 .	26.244	26.244	.000	
March 31	26.355	26.356	.001	
April 8	26.409	26.411	.002	
April 10	26.254	26.257	.003	
October 25...	26.512	26.513	.001	After return of instrument from service at Furnace Creek.

* Each of these "Corrected means" is the mean of five readings at intervals of one hour corrected for temperature and instrumental error.

Peculiarly enough, however, this barometer (No. 349) was reported by the observer to be in bad condition and was returned to this office wholly unserviceable; a condition of affairs that seems scarcely possible, except to have been induced by ill treatment after the term of service of the instrument had expired.

In view of these circumstances, therefore, the pressure observations at Furnace Creek can be relied upon as *of as great accuracy as any that we can hope to attain with any single instrument of this type.*

RAIN GAUGE.

The Weather Bureau standard rain gauge is constructed of drawn brass tubing and galvanized iron. The receiving rim, or collector, of the rain gauge is 8 inches in diameter and formed of heavy drawn brass tubing, very accurately sized, and turned to a knife edge around the top edge. The funnel-formed bottom has a slope of 45°, with a hole at the center about $\frac{1}{2}$ inch in diameter. The measuring tube is also drawn brass tubing, very accurately sized to have $\frac{1}{10}$ the area of the 8-inch collector. An outer cylinder of galvanized iron, 8 inches in diameter, surrounds and shelters the measuring tube and supports the funnel-shaped receiver, serving, also, as overflow in case of heavy rainfall. The measuring tube is 20 inches high and, consequently, will contain 2 inches of rainfall. The depth of the water in the measuring tube is determined by the insertion of a carefully graduated cedar stick, divided to inches and tenths. The sectional area of the stick is less than $\frac{1}{100}$ of that of the tube.

SHELTER.

For the exposure of the thermometers, hygrometer, and thermograph, a standard size instrument shelter was furnished, but of special construction to secure lightness and facility in transportation, as well as in the setting up of the shelter at its destination. The interior free space was approximately cubical, nearly 3 feet on a side. The roof was double, with an air space from 6 to 8 inches high, open at the north and south fronts of the shelter.

The louver sides of the shelter were composed of slats nearly 1½ inches from center to center and about 4 inches wide, inclined at an angle of 45°. The floor consists of strips lying close together, and is, therefore, practically continuous, permitting but little or no vertical circulation of air. This shelter was mounted upon wooden posts so that its floor was 5 feet above the ground, and with the sides respectively north and south and east and west. The office building was at a distance of about 105 feet.

THERMOGRAPH.

This recording instrument was also of the Richard Bros. construction, but of somewhat special type in order to more nearly satisfy the requirements of this Bureau than the instruments generally supplied. The temperature scale of this instrument extends from —20° to +110° F., and the cylinder makes two revolutions per week, instead of one as is the general case, thus rendering smaller periods of time perceptible. The clock movement, itself, was also of a superior quality to give better results.

We regret to add that after extended experience with these French instruments and particular efforts at improvement in the clock movements, we find there is still much to be desired, and that serious errors arise from imperfect clock performance, not to mention the thermometric action itself.

The thermometer part of the instrument, as is perhaps quite generally known, consists of a short curved piece of flat metal tubing, having a section shaped much like a very flat ⬭. Such tubes have the peculiar property of tending to straighten out when subjected to internal pressure, and this is utilized in the present instance to measure temperature by filling the tube with alcohol or similar liquid, the expansion of which with temperature changes gives slight motion to the curved tube, one end of which is fixed while the other, through a system of magnifying levers, communicates motion to a delicate pen tracing its varying positions upon the usual drum of paper. An adjusting screw connected with the fixed end of the thermometer's bulb enables the pen to be set to any particular line on the sheet. By this means the pen could be set low enough on the sheet to take in the very high temperatures at Furnace Creek station. The space on the record sheet corresponding to 1° F. is about .03 of an inch only, and for reasons similar to those given in discussing the barograph, the thermograph also is only a differential instrument and its readings must be constantly corrected for varying instrumental errors.

In transcribing from the record sheets of both thermograph and barograph, observers are directed to apply corrections to the hourly readings of the instruments so as to make the readings at the hours of regular observations agree with the eye readings of the standard

instruments. For intermediate hours interpolated corrections are used, which latter are very conveniently determined by aid of a graphical "Correction card," devised at this office some years since, but not heretofore described. A stiff piece of card is ruled and figured as shown in Fig. 2, and small notches cut in two opposite edges at the extremities of one set of lines. A rubber band is stretched across the card and set in notches corresponding to the observed corrections that must be applied to the readings at the 8 o'clock observations. Obviously, the corrections at intermediate hours will be given by the intersection of the rubber band with the particular hour line in question. Moreover, if a real correction is found by observation at any intermediate hour, a pin may be stuck through the card at the proper point, or points, and the band deflected to correspond, as shown in the figure. All the hourly readings taken from the barograph and thermograph traces have been corrected in accordance with these principles.

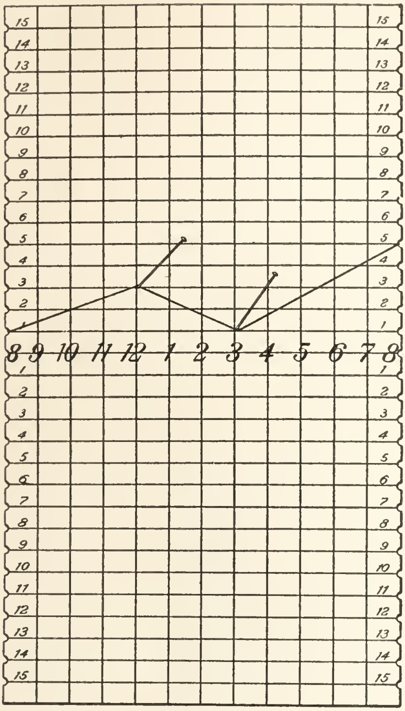

Fig. 2.

THERMOMETERS.

Owing to the extremely high temperatures reported to prevail within the Death Valley region, it was necessary to provide thermometers for higher temperatures than those at regular stations. These were made by H. J. Green, Brooklyn, N. Y., and were unusually nice and all stem-graduated to degrees Fahrenheit. The bulbs of the maximum and minimum thermometers were spherical, about $\frac{3}{8}$ inch in diameter. The remaining thermometers had cylindrical bulbs of between $\frac{1}{8}$ and $\frac{3}{16}$ inch diameter, and from $\frac{1}{2}$ to $\frac{5}{8}$ inch long. With the exception of the "small" psychrometer No. 37 the graduations ranged from 16° to 18° to the inch, rendering tenths of degrees readily perceptible. The corrections to reduce to the standard air thermometer were carefully determined before the instruments were sent out. These corrections, for all the thermometers, are given in the table below.

The exposure of the thermometers within the shelter is described as follows:

Passing east and west across the middle of the shelter inside is fixed a wooden strip about 3 inches wide, to which is secured the maximum and minimum thermometers with their bulbs to the eastern side of the shelter. The wet and dry bulb thermometers, for obtaining air temperature and humidity, are placed to the right of these and toward the western end of the strip.

Corrections to thermometers at Furnace Creek, Cal., September 30, 1891.

Scale reading.	Exposed.		Psychrometers.				Maximum.		Minimum.	
			No. 37.		No. 47.					
	No. 3426.	No. 3431.	Dry. No. 2758.	Wet. No. 2734.	Dry. No. 3430.	Wet. No. 3427.	No. 2761.	No. 2762.	No. 2197.	No. 2545.
°	°	°	°	°	°	°	°	°	°	°
32	0.0	0.0	0.0	0.0	0.0	0.0	−0.1	−0.1	+0.2	+0.4
42	+0.1	0.0	0.0	0.0	0.0	+0.1	−0.1	−0.1	+0.3	+0.6
52	0.0	0.0	+0.1	0.0	−0.1	0.0	+0.1	0.0	0.0	+0.2
62	0.0	0.0	+0.1	+0.1	−0.1	0.0	−0.1	−0.1	+0.1	+0.3
72	0.0	0.0	0.0	0.0	0.0	0.0	−0.2	−0.2	+0.1	+0.3
82	−0.1	−0.1	0.0	0.0	0.0	−0.1	−0.1	−0.1	0.0	+0.3
92	−0.1	+0.1	0.0	0.0	0.0	−0.1	−0.1	−0.1	0.0	+0.2
102	−0.1	−0.1	+0.1	+0.1	−0.2	−0.1	−0.2	−0.1	....	+0.1
112	0.0	−0.1	....	....	+0.1	0.0	−0.2	−0.1	....	+0.1
122	+0.2	−0.1	....	....	−0.2	+0.2	−0.3	−0.2	....	+0.1
132	+0.2	+0.2	....	....	−0.1	+0.3	−0.1	−0.1	....	+0.4
142	−0.1	+0.1	....	....	−0.1	0.0	0.0	0.0	....	+0.6
152	−0.1	+0.3	....	....	−0.1	0.0	−0.1	−0.1	....	+1.0

The thermograph was placed upon the floor of the shelter.

The maximum and minimum thermometers were mounted as shown in the accompanying cut. The wet and dry bulb thermometers, forming the hygrometer, appeared as shown in Fig. 3. In view of the greater accuracy to be secured by the use of the whirled psychrometer, two of these instruments were furnished the observer, and readings were made at each observation.

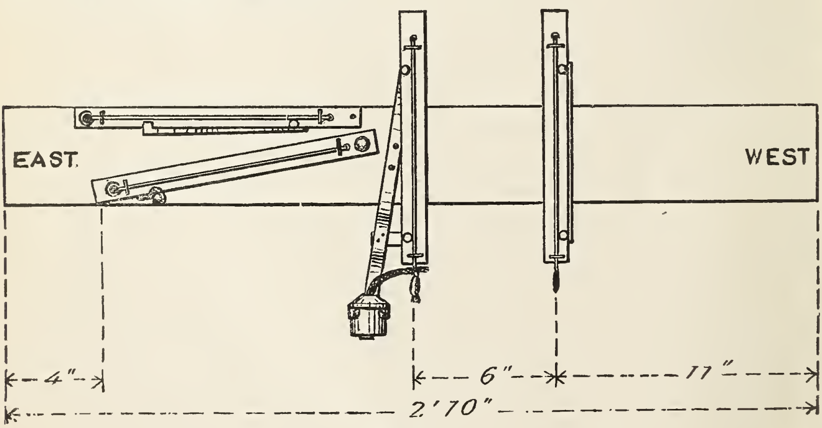

Fig. 3.

A matter of the greatest importance in the construction of the sling psychrometers is that they be exceedingly light, otherwise the arm of the observer becomes very quickly fatigued by a very few observations and the instrument proves a great annoyance. It is frequently written

that a sling psychrometer may be easily made by tying the thermometers back to back, or otherwise, and attaching a foot or so of stout cord to a ring or eye at the top of the metal back. Anyone using such a device quickly finds his forefinger seriously rubbed and made sore by the abrasion of the cord. The type of instrument used at Furnace Creek consisted of two thermometers attached side by side to a light strip of aluminium, the wet bulb being considerably below the dry. About 6 inches of light chain of very strong construction is attached to the eye at the top and fitted with a small wooden handle so arranged as to permit of the free movement of the chain in the whirling of the thermometers. A substitute for the chain is often used, consisting of a special swivel and link arrangement that is rather stronger and safer than the chain. This constitutes the standard pattern of whirled psychrometer used by the Weather Bureau, and is shown in Fig. 4. Either form is very light and convenient, and constitutes probably the best simple instrument available for easily securing accurate air temperatures and humidities.

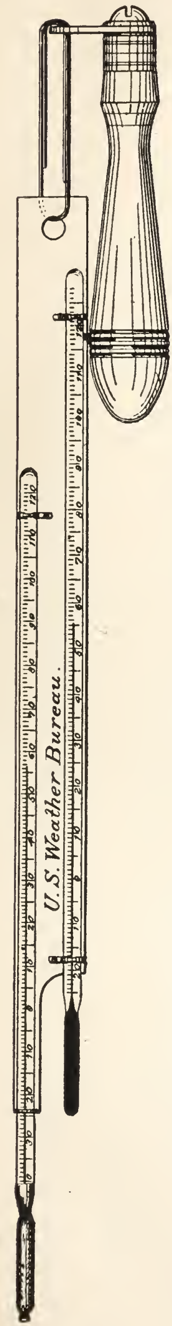

FIG. 4.

On June 5 one of the psychrometers at Furnace Creek was broken because of a defective link in the chain, and still later the wet bulb thermometer of the extra instrument was broken by a falling book while in the office. From this date until the station was closed readings from the stationary psychrometer only were taken.

WIND VANE.

Inasmuch as the direction of the wind is so easily ascertained without the aid of a special instrument none was sent with the equipment for this station, the observer being instructed to display a small streamer or string from some convenient object in a proper locality, and take wind directions accordingly. The point selected by the observer was from a staff attached to the corner of the instrument shelter and at a height of 10 feet above the ground. The north point was located by aid of a small prismatic compass; an allowance of 15° east being made for magnetic variation.

III.—DISCUSSION OF OBSERVATIONS.

The air-pressures obtained by the observations in Death Valley (see Table I at the end) afford several features of interest. The mean pressure for the five months, obtained from the hourly readings, is 29.96 ($760.98^{mm.}$), and this is not reduced for elevation. The average pres-

sure for July is 29.92 inches, or almost exactly 760^{mm}. The July pressures observed in this region, as plotted in Hann's "Atlas der Klimatologie," is 760^{mm}., so that this station is apparently near the level of the sea. The use of the mean monthly pressures compared with simultaneous observations at Yuma, San Diego, Los Angeles, and Keeler, the nearest stations, when used to obtain the elevation of this station, gave very discordant results, varying nearly 300 feet.

The maximum pressure observed was 30.30 on May 22, the minimum 29.41 on September 30. The absolute range for the five months was, therefore, 0.89 inch, a quantity not generally surpassed by other stations in the summer season. The monthly ranges as compared with those of other stations are large, as shown in the accompanying table. They are decidedly larger than those for any station around Death Valley. In general, these ranges are largest in the northeastern part of the United States and decrease as we pass south or west. The ranges in Death Valley approximate those found at Eastport, as shown in the table. The Death Valley monthly ranges are greater than in the greatest part of the United States.

Monthly ranges of barometer, 1891.

Station.	May.	June.	July.	Aug.	Sept.	Average.
	Inch.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
Death Valley, Cal	0.71	0.64	0.51	0.49	0.88	0.65
Santa Fé, N. Mex	0.52	0.37	0.32	0.30	0.48	0.40
El Paso, Tex	0.46	0.34	0.36	0.33	0.55	0.41
Fort Grant, Ariz	0.34	0.28	0.27	0.28	0.33	0.30
Yuma, Ariz	0.31	0.31	0.36	0.40	0.54	0.38
San Diego, Cal	0.19	0.21	0.26	0.26	0.39	0.26
Los Angeles, Cal	0.25	0.21	0.26	0.29	0.40	0.28
Keeler, Cal	0.53	0.34	0.36	0.37	0.53	0.43
Fresno, Cal	0.49	0.36	0.45	0.38	0.44	0.42
Sacramento, Cal	0.56	0.34	0.45	0.38	0.45	0.44
Salt Lake City, Utah	0.73	0.46	0.48	0.47	0.55	0.54
Eastport, Me	0.89	0.93	0.72	0.61	1.05	0.84

This peculiarity is to be attributed, in part, at least, to the enormous daily range of pressure in Death Valley. The evening pressures are almost invariably lower than the morning ones. The mean difference for May was 0.19 inch, and for the other months in succession 0.22, 0.22, 0.21, and 0.22. This gives an average of 0.212 inch. Mr. E. G. Johnson, who has assisted me much in getting together the necessary data, compiled the following list to show how this compares with other stations. The data are for 1891, except those for Vienna, which are for 1889, and all are for the same months of the year:

Furnace Creek, Cal., average monthly range	0.212 inch.
Boston, Mass., average monthly range	0.146 inch.
New York City, N. Y., average monthly range	0.129 inch.
Washington, D. C., average monthly range	0.121 inch.
Yuma, Ariz., average monthly range	0.112 inch.
Santa Fé, N. Mex., average monthly range	0.105 inch.
San Diego, Cal., average monthly range	0.066 inch.
Vienna, Austria, average monthly range	0.112 inch.

The mean daily range of the barometer in summer is (as will appear later) very large at Death Valley. This will generally be added to make the monthly maximum, and subtracted in making the monthly minimum, thus increasing the monthly range by approximately twice its amount. Taking this out from the monthly ranges, the Death Valley datum approximates that of Yuma, Ariz., San Diego, Cal., and Santa Fé, N. Mex., and it appears that the pressure in the Valley is submitted to about the same non-periodic changes as that at stations outside, as must, of course, be the case.

The daily temperatures are given in Table II at the end of this bulletin. The absolute maximum was 122° F., and this was reached on several days; three days in succession, on June 30 and July 1 and 2, and again two days in succession in August. This is an excessive maximum, but it has been surpassed in the United States. In July, 1887, at Mammoth Tank, in the Colorado Desert, the temperature reached 128° F. in the shade, and again in July, 1884, it was reported at 126° F. The highest temperature ever reported at any other regular Weather Bureau station was 118°, at Yuma, in 1878. In 1891 the maximum temperatures were the highest ever reported at stations in the interior of the Pacific coast states south of the Columbia River. They were about 110° in the San Joaquin, Sacramento, and lower Colorado valleys in July and August.

The lowest point to which the temperature fell while the station was occupied in Death Valley was 54°, on May 21. Generally the minimum was above 70°, and it not infrequently reached 90°; the highest was 99°, on July 18. A day during which the maximum temperature is 120°, the minimum 99°, and the mean of all hours 108°.6, would not be a comfortable one to pass, yet such a day was passed by the observer in Death Valley on July 18, 1891.

The absolute range of temperature for this period was 68° (54°, 122°). This is not excessively large for so long a period as five months. The greatest daily range was in May, 37°; in June, 44°; in July, 42°; in August, 42°; in September, 41°. These are large, perhaps a half larger than usual over the states, but they can easily be surpassed.

To give some idea of the character of the temperature in Death Valley, as compared with other places in the United States, the following table for July, 1891, may be of service:

Temperatures in the United States, July, 1891.

Stations.	Mean.	Maximum.	Minimum.	Mean maximum.	Mean minimum.	Largest daily range.
	°	°	°	°	°	°
Death Valley, Cal	102.1	122	72	115.6	86.8	42
Yuma, Ariz	92.5	114	64	108.0	76.0	39
Keeler, Cal	81.6	100	57	94.0	69.0	31
Fresno, Cal	83.6	114	51	101.0	66.0	39
San Diego, Cal	69.0	88	58	75.0	63.0	21
Washington, D. C	72.0	89	54	81.0	63.0	29
Chicago, Ill	67.0	87	55	73.0	60.0	22
Rio Grande City, Tex	87.6	105	70	101.0	74.0	29
Mount Washington, N. H	46.0	64	29	52.0	40.0	22

These are all regular stations of the Weather Bureau. Excessive temperatures more nearly approaching those of Death Valley could probably be easily found among the voluntary stations to the south and southeast of this place.

The mean monthly temperatures were 84°.7, 92°.1, 102°.1, 100°.8, 90°.2, for the months in order. For four months the mean temperature was above 90° and for two above 100°. The mean temperature for all five months was 94°. The reputation of the valley for heat is certainly justified.

The period during which the observations were taken includes the hottest part of the year, and it will be interesting to ascertain the time of maximum heat. The records show that the seven days from July 18 to 24, inclusive, was a continuous hot spell, with the highest temperature of any consecutive days of the same number. The minimum did not fall below 88°, and the maxima ran from 119° to 121°. The daily temperature did not fall below 106°.4, and averaged 107°.5. A smooth curve run through the monthly means gives July 24 as the date of annual maximum. This is somewhat later than usual for the Eastern States but not remarkable for the Southwest. It may be a few days later than would be shown by observations for a series of years, as the heat held late in the summer of 1891.

Humidity.—An interesting point in connection with this valley is that of its aridity. It has already been pointed out that water probably stands in the valley occasionally, but this would not happen in the dry season, and the months of observation fall in this season. The average amount of moisture is remarkably constant through the months, as is shown by the uniformity of the dew-points, and consequently that of the weights of vapor in the air. It is also fairly the same at the morning and evening observations. We may conclude that during the months the average quantity of vapor does not vary much in this independent basin in the midst of an arid region and cut off by high mountains east and west. There is a slight deficiency of 0.28 grain per cubic foot at the evening observations as compared with those of the morning, but it is probably due to the rising currents of air during the hottest parts of the day.

Mean dew-points and absolute humidities in Death Valley.

	Dew-point.		Water in grains Troy, per cu. ft.		Mean temperatures.	
	5.13 a.m.	5.13 p.m.	5.13 a.m.	5.13 p.m.	5.13 a.m.	5.13 p.m.
	°	°			°	°
May	41	40	2.97	2.86	73	94
June	42	42	3.08	3.08	81	102
July	49	48	3.95	3.81	89	112
August	48	46	3.81	3.55	87	111
September	47	48	3.68	3.81	79	98
Average	45	45	3.70	3.42	82	103

Dew could not form in the valley under the conditions observed. The maximum approach to dew was on the morning of August 17. The dew-point was then 70°, but the temperature was 79°. There was present only 75 per cent. of the moisture necessary to form dew, but if the temperature had fallen only 9° dew would have begun. The least approach to dew was at the evening observation on August 4. The dew-point was then 22° and the actual temperature in the shade was 112°. There was present only 5 per cent. of the moisture needed to have dew form, and the temperature would have to fall 90° to make it possible. The average dew-point for the whole period (observations twice daily) was 45°, but the mean temperature for the same hours was 93°. The moisture would have to be quintupled or the mean temperature fall 48° lower to make dew possible under these conditions.

But the most interesting form of humidity by which to judge of the comfort to be found in residence at a place, and the animal and plant forms which will thrive in it, is the relative humidity. This is given twice for each day in Table III. The lowest recorded relative humidity in Death Valley was 5 per cent. on the afternoons of August 4 and 5. This was part of a long dry spell. From July 30 to August 9 the relative humidity did not go above 13 per cent. at the afternoon observation, and averaged 8. The highest observed was 75 per cent. on the morning of August 17. The morning observations here were at 5 hrs. 13 min., or about the time of the diurnal maximum of relative humidity, while the evening observations fell shortly after the usual minimum. The observed humidities at these hours are therefore the approximate diurnal maxima and minima, and this gives the accompanying abstract from Table III an interest it would not otherwise have.

Relative humidities in Death Valley.

1891.	Morning.	Evening.
	Per cent.	*Per cent.*
May	34.5	17.8
June	27.2	14.2
July	27.4	12.6
August	29.0	13.0
September	34.2	20.3
Average	30.5	15.6

The difference between morning and evening is due to the difference in temperature for the most part, as it has been already shown that the average moisture is nearly constant. It appears that in the morning the air contains less than one-third the amount of saturation and in the evening less than one-sixth. This will be most instructive if we compare the humidities in Death Valley with other places in the United States. This is given in the tabular statement accompanying, and includes the driest stations, those nearest to Death Valley, the dampest regular station for this season (Fort Canby, near the mouth of the Columbia), and Chicago and Washington for comparison. The

record for Fort Grant, Ariz., is not complete, as this station was abandoned in August. It appears to stand next in aridity to Death Valley. At Winnemucca, in August, the dryness was greater than in Death Valley. The aridity of Death Valley can be best judged by comparing it with the relative humidity at Chicago, 72 per cent.; Washington, 77 per cent., and Fort Canby, 96 per cent. Its reputation for aridity in summer seems fully justified, for the low relative humidity (with the large air-motions to be mentioned) would cause evaporation to proceed with very great rapidity.

Relative humidities in the United States, 1891.

Stations.	May.	June.	July.	August.	September.	Average.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Death Valley, Cal	26	21	20	21	27	23
Fort Grant, Ariz	32	26	33	....	....	....
El Paso, Tex	35	26	31	36	40	34
Winnemucca, Nev	49	42	27	18	36	34
Keeler, Cal	38	31	31	35	38	35
Fresno, Cal	52	42	30	31	41	39
Yuma, Ariz	39	37	36	47	40	40
Santa Fé, N. Mex	62	47	44	42	56	50
Sacramento, Cal	74	60	56	59	56	61
Chicago, Ill	67	81	70	74	66	72
Los Angeles, Cal	78	73	73	75	69	74
San Diego, Cal	75	75	78	78	77	77
Washington, D. C	68	74	77	82	83	77
Fort Canby, Wash	92	97	97	96	97	96

The cloudiness was slight (Table IV). In May there were 12 clear days and 14, 15, 17, and 12 in the other months in succession. This makes 70 clear days in 153, or 46 per cent. of days without clouds. In the latter part of July and early in August there were 12 clear days in succession. Only 4 of the 153 days were entirely overcast. The average percentage of cloudiness for five months was 30. This is decidedly greater than for stations around Death Valley, Cal., with very similar physical conditions. Pioche, Nev., had 25 per cent.; Prescott, Ariz., 23; Yuma, Ariz., 14; Visalia, Cal., 14; and Keeler, Cal., 10 for the same period. The greater cloudiness of Death Valley is due to the local storms for which the surroundings of the valley are especially favorable.

There was an appreciable difference in the cloudiness of the morning and evening. For the morning it was 24, 18, 29, 15, and 10 per cent., for the months in order; for the evening observations, 39, 27, 28, 23, and 30 per cent. The general average for the morning was 19 per cent.; for the evening, 29 per cent., or one-half greater.

Cirrus and cumulus types of clouds were about equally common, generally cirro-stratus and cumulo-stratus. This means that the clouds were about equally of general and local origin. Light haze was reported but twice, dense haze but once. The direction of motion of clouds was quite various, but the prevailing directions were, for the months in succession, south, west, southwest, west, and south. The westerly direction was the prevailing one in summer.

The *rainfall* was extremely light. The showers at the station at Furnace Creek are given in the accompanying table:

Rains and accompanying phenomena at the station.

1891.	Beginning.			Rainfall.		Fall of temperature.	Rise of barometer.	Change of wind.	Notes.
	Time.	Temperature.	Humidity.	Duration.	Amount.				
		°	*Pr. ct.*	*h. m.*	*Inches.*	°	*Inches*		
May 21...	2.33 a. m.....	64.5	48	3 10	0.14	9.3	......	....	
Do ..	10.28 a. m.....	68.2	44	0 05	trace.	......	......	none......	Light showers.
Do ..	11.18 a. m.....	72.3	41	0 10	trace.	......	......	none......	Do.
Do ..	5.28 p. m.....	75.0	40	2 55	trace.	......	......	....	Do.
May 24...	3.25 p. m.....	92.3	18	0 05	trace.	4.8	0.03	none......	
May 31...	During night .	....	......	......	0.04	......	......	....	Very light sprinkle.
June 3...	4.53 a. m.....	88.3	28	0 44	0.05	1.3	0.03	....	Light showers.
Do ..	1.23 p. m.....	92.0	22	0 18		1.0	......	....	Do.
June 13..	3.33 p. m.....	86.0	22	0 08	trace.	3.0	0.05	s. to ne...	Thunderstorm.
July 22 ..	4.56 a. m.....	99.1	8	0 07	trace.	2.6	......	....	Light sprinkle.
Do ..	9.18 a. m.....	108.3	8	0 02	trace.	0.5	......	....	Do.
July 24 ..	10.58 p. m.....	106.6	14	0 25	trace.	14.9	0.19	sw. to se..	Thunderstorm.
July 25 ..	8.13 p. m.....	112.0	11	2 15	0.09	18.5	0.58	nw. to e ..	Do.
July 26 ..	10.13 p. m.....	98.0	15	1 45	0.04	7.5	0.13	none......	Tornadic wind.
July 27 ..	6.30 p. m.....	106.8	11	......	0.24	19.9	......	s. to e	Thunderstorm.
Aug. 16 ..	2.23 a. m.....	92.2	18	2 20	0.54	14.2	0.10	ne. to se..	Do.
Do ..	8.43 p. m.....	98.1	18	3 15	0.06	14.6	0.30	....	Do.
Sept. 5...	12.13 a. m.....	100.8	28	1 12	0.04	4.9	0.08	ne. to w ..	Do.
Do ..	3.43 p. m.....	107.0	29	1 10	0.08	17.5	0.24	n. to ne...	Do.
Do ..	7.43 p. m.....	87.5	54	0 15	0.06	4.0	0.12	none......	
Sept. 6...	7.33 p. m.....	84.5	63	0 15	trace.	......	0.03	....	
Do ..	9.58 p. m.....	92.4	50	0 40	0.02	5.8	0.05	....	

There were 22 showers at Furnace Creek during the 5 months it was occupied as a station. The observer also recorded 9 other cases in which rain was seen to fall on the mountains or there was evidence of a thunderstorm within sight. Of the 22 cases of rainfall at the station, only 13 gave more than a trace, or measurable amount, of rain. These 13 showers fell on 9 different days, and this gives the probability of rain on any day at 9÷153, or 0.06. This is larger than for the stations around Death Valley for the same months; at Yuma the average probability is 0.01; at San Diego, 0.04; at Keeler, 0.04; at Frisco, 0.12; at Prescott, 0.19.

The total rain in the months is, for May, 0.18 inch; for June, 0.05; for July, 0.37; for August, 0.60; for September, 0.20. For the entire period of 5 months the rainfall was 1.40 inches. This, for the dry season, is by no means very dry, but the excessively low humidity and brisk winds evaporate the rain rapidly.

The last column in the table of rainfall shows the character of the rain very distinctly. The rain was always either a slight sprinkle or a thunderstorm, and was, therefore, local in character. There was no general or "blanket" rain during the occupancy of the valley by the observer.

An additional feature is brought out by the columns of temperature and humidity which have been added, and this is of interest in its bearings on rains in arid regions generally. The observations of the

wet-bulb thermometer, from which the humidity is deduced, were taken only at 8 a. m. and 8 p. m., hence the humidity cannot be given directly for the intermediate hours, but the hours of observation were near enough generally to permit the following conclusion: *The lower, or surface, air was at no time at or near saturation at the time of rainfall.* During the rainfall in the morning of May 21 the lower air had only 62 per cent. of the moisture of saturation, and during the morning of June 3 only 48 per cent. The nearest hour of observation on July 22 (only 10 minutes after the rain) gave only 20 per cent., and correspondingly with the others. But it will be more interesting to estimate the relative humidity at the time of the beginning of each shower, and this we can easily do by interpolation of the dew-point at the hours of observation. It has been already pointed out that the mean absolute humidity, and hence the mean dew-point, is curiously constant. An inspection of the sheets of observations shows that the dew-point actually changes but slowly and is not infrequently the same in successive observations. Deducing the relative humidity in this way, column six is obtained, and the interesting fact appears that at the beginning of the rains the relative humidity was never greater than two-thirds, was sometimes as low as one-twelfth, and averaged 28 per cent. In the very heaviest rain it was only 18 and it was 63 in one of the lightest—so light that the amount of rain that reached the ground was not measurable. It is a common phenomenon in arid regions, and not unknown elsewhere, to see rain fall from the clouds and fail to reach the ground. At such times the condition of the air at the height of the clouds, where there must be saturation, is very different from that at the surface. At Furnace Creek the superheated air near the ground was apparently a relatively thin layer, so thin that rain-drops formed above could pass through it without entire evaporation notwithstanding its great heat and low humidity. On August 16 over half an inch passed through it, though its relative humidity was only 18 per cent.

It is to be noted, also, that the rain showed a distinct diurnal frequency. Nearly all of the hours of rain were in the night; out of 50 hours of rain 35 occurred from 7 p. m. (local time) to 5 a. m., or from sunset to sunrise. There were only 15 in the hours when the sun was above the horizon. The hours of rainfall during the night were pretty evenly distributed after 8 p. m. (local time).

The winter rains for this place have not been recorded, but as in summer its cloudiness and rainfall compare very favorably with stations about it there is every probability that it has at least the rainfall belonging to its geographical position, with possibly some addition due to the favorable character of the topography for summer rains. To ascertain what this is, the following records are extracted from Lieutenant Glassford's "Irrigation and Water Storage in the Arid Region:"

Rainfall at stations near Death Valley.

Station.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.	Length of record.
	Inch.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Yrs.*
Keeler, Cal	0.28	0.38	0.26	0.41	0.31	0.16	0.14	0.08	0.20	0.28	0.41	0.49	3.40	6.2
Camp Independence, Cal	1.22	0.56	0.52	0.21	0.27	0.04	0.11	0.22	0.07	0.32	0.21	2.26	6.01	11.7
Bishop Creek, Cal	1.19	0.50	0.52	0.17	0.12	0.10	0.03	0.00	0.02	0.03	0.35	0.61	3.64	6.7
Camp Cady, Cal	0.18	0.50	0.37	0.25	0.08	0.00	0.34	0.63	0.00	0.30	0.27	0.16	3.08	2+
Barstow, Cal	0.25	0.10	0.46	0.04	0.06	0.00	0.00	0.13	0.07	0.23	0.70	3.87	5.91	1.6
Daggett, Cal	0.48	1.44	1.17	0.10	0.49	0.00	0.00	0.03	0.00	0.00	0.00	0.29	4.00	1.1
Fenner, Cal	0.15	1.30	1.25	0.15	1.09	0.05	0.00	0.00	0.03	0.00	0.00	2.40	6.42	1.2
Needles, Cal	1.68	0.64	1.14	0.10	0.75	0.00	0.04	0.64	0.06	0.12	0.00	2.20	7.37	1+
El Dorado Cañon, Nev	0.64	0.28	0.59	0.15	0.01	T.	1.19	0.61	0.38	0.47	0.54	3.70	8.56	2.7
Yuma, Ariz	0.31	0.39	0.14	0.07	0.00	0.00	0.33	0.66	0.58	0.09	0.30	0.29	3.16	28.0

The second and third stations in this table are in higher latitudes than Death Valley, the others in lower. Camp Cady and the three following are in the Mohave Desert; the last three are on the Colorado River.

For the months covered by the Death Valley records Keeler has 0.89 inch of rainfall; Camp Independence, 0.71; Bishop Creek, 0.27; Camp Cady, 1.05; Barstow, 0.26; Daggett, 0.52; Fenner, 1.17; Needles, 1.49; El Dorado Cañon, 2.19; Yuma, 1.57.

All the stations off the Colorado River give less rainfall in summer than Death Valley, 1.40. The mean of the two nearest, Keeler and Camp Cady, gives a summer rainfall of 0.97 inch, and an annual of 3.24. If Death Valley winter rainfall is as much larger in proportion as is the summer rainfall, this would give it an annual amount of 4.50 inches. Lieutenant Glassford passes his isohyetal of five inches nearly over it, and we may assume, with probability of close approximation, that the annual rain in Death Valley is at least 4 or 5 inches. This is not heavy, but it is heavier than in the desert to the south, as the topography would lead us to expect.

Winds.—Table V gives the direction of the wind at each observation for each day of the five months, and the mean of the velocities of all the hours of the day. Compilation shows that the average frequencies for each month are as follows:

Monthly frequency of wind in Death Valley, Cal.

Direction of wind.	By months.						Average for morning.	Average for evening.
	May.	June.	July.	August.	September.	Average.		
North	6	6	4	0	11	5.4	8.0	2.8
Northeast	3	5	2	2	5	2.4	5.2	1.6
East	4	2	0	3	1	2.0	3.6	0.4
Southeast	29	13	12	10	4	13.6	19.2	8.0
South	16	13	34	32	34	25.8	16.8	34.8
Southwest	1	11	5	6	2	5.0	2.0	8.0
West	1	2	1	4	0	1.6	1.6	1.6
Northwest	1	8	4	2	3	3.6	3.2	4.0
Calm	1	0	0	3	0	0.8	1.6	0.0

It appears that the "sluggish atmosphere" to which writers are fond of referring when describing Death Valley exists only in their imagination, at least in summer. The calms observed in five months in bi-daily observations were only four, and these were all in the morning hour about the time of minimum velocity of wind. From the 306 observations there result only 4÷306, or one per cent. of calms. Yuma, Ariz., in these months in 1889 had 9 per cent.; Keeler, Cal., 10; San Diego, Cal., 16; and Los Angeles, Cal., 28. But records on this point vary much with the station. San Antonio, Tex., in these months had no calms, while Roseburgh, Oregon, had 30 per cent.

The prevailing wind was from the south, nearly one-half of all being from that direction. The north winds were only one-fifth as frequent, notwithstanding the valley lies nearly north and south. The prevailing wind at Keeler was also from the south, but at other stations near this the south wind is not so common—though there is some evidence of a summer monsoon over southeastern California, and this would give generally southerly winds.

The relation of the direction of the wind to questions of temperature and speed also deserves attention. In the accompanying table is given the average temperature and speed of the winds from each point of the compass and also the per cent. of frequency of the highest wind velocity from each point of the compass.

Relations of direction to temperature and velocity.

Direction of wind.	Average temperature.	Average velocity.	Frequency of daily maximum velocity.
	°	*Miles.*	*Per cent.*
North	83	6.0	6
Northeast	80	6.6	6
East	79	8.2	2
Southeast	86	7.2	15
South	98	12.6	55
Southwest	102	10.1	8
West	97	4.0	3
Northwest	90	5.8	5

It will be seen that the winds from down the valley are notably hottest, those from across the valley next, and those from up the valley and from the mountains east follow in order. The winds from down the valley are also those of highest velocity, and also those giving the most frequent maximum velocities.

There is also some evidence of the diurnal change of wind, as appears in the last two columns of the table on page 27 (where the numbers are doubled to make them comparable with the preceding column). This feature is better shown in the accompanying wind roses, Fig. 5. The south winds are more than twice as frequent in the evening as in the morning, and the north winds less than half as frequent. This is a natural result of the heating and cooling of the higher valley to the north.

The mean hourly wind velocities are not materially different from those at other stations. On August 5 they averaged 25.9 miles, but on September 7 only 2.3 miles. The average of all the months was 9.8 miles. The average at Phœnix, Ariz., is only 2.4 miles for the same period; at San Diego, 5.9; at Yuma and Santa Fé, 6.1; and at San Francisco, 11.1. On the whole, the velocity in Death Valley is greater than at neighboring stations.

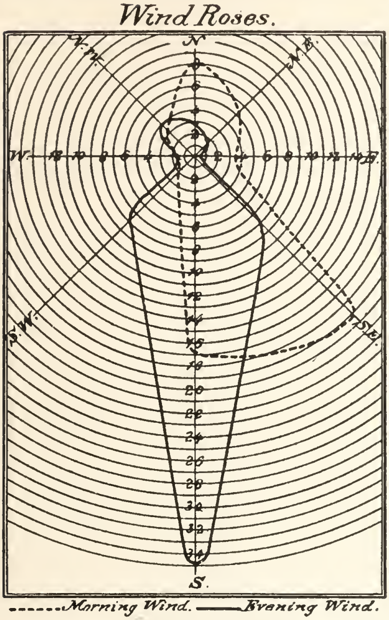

Fig. 5.

Before leaving this part of the discussion it will be interesting to see if such a climate can be equaled in other parts of the earth. The climate of Death Valley in summer is very hot and very dry; at the same time the weather is more cloudy than would be expected; there are some rains, and the winds are fairly active.

If the hottest month of the year is taken (usually July for the northern hemisphere and January for the southern) the regions of excessive heat will be found to be—

The central Sahara with a mean temperature in July of 97° and upwards;

Interior Arabia and westward to the Indus, temperature of July 94° and upwards;

Southern California to Sinaloa, temperature of July 94° and upwards;

Central Australia, temperature of January 94° and upwards.

The center of greatest heat in India migrates a little on account of the summer rains. In May it is central in the peninsula, and the mean temperature is 95° and upwards. In July the temperatures are reduced.

In general these places are in latitudes 20° to 40°, and they are all very dry—generally sandy deserts. Death Valley is in one of these areas, but its topography and soil are especially adapted for producing very high temperatures. To show the character of these differences, four stations in the valley of the Indus and one in the Tunisian Sahara have been selected as marked by especial heat and dryness—the most extreme found where regular observations are taken. The places selected are—

Gardaia, a small irrigated oasis, filled with orchards, in the Tunisian

Sahara, about 175 miles southwest of the Gulf of Gabes, population 12,000;

Hyderabad, a city of 35,000 inhabitants on the Indus, and Jacobabad, 5,000 inhabitants, near the Belochee frontier, both in upper Sinde;

Mooltan, a city of 69,000 inhabitants, formerly much more populous, and Dera Ismail Khan, 12,000 inhabitants, both in the Punjaub.

All these places are celebrated for their great dryness and excessively hot summers.

Comparison of Death Valley and other stations.

Stations.	Month of greatest heat.	Mean temperature.	Absolute maximum.	Mean maximum.	Mean minimum.	Mean daily range.	Relative humidity.	Cloudiness.	Rainfall.	No. of rainy days.	Elevation.	Years of observation.
		°	°	°	°	°	%		*Inch.*		*Ft.*	
Death Valley, Cal	July ..	102.1	122.0	115.6	86.8	29	20	31	0.13	0.37	.....	1891
Sinde:												
Hyderabad..................	May ..	91.0	121.0	106.0	78.0	28	45	7	0.10	1.00	94	8
Jacobabad	June..	96.0	122.2	111.0	83.0	28	42	11	0.10	1.00	186	9
Punjaub:												
Dera Ismail Kahn...........	June..	93.0	121.5	107.0	80.0	27	44	16	0.60	2.00	573	11
Mooltan	June..	94.0	118.4	107.0	82.0	25	51	10	0.40	2.00	420	11
Tunisian Sahara, lat. 32° 35′												
Gardaia......................	July ..	96.0	118.4	111.0	78.0	29	25	7	0.08	1.00	706?	1887

It will be seen that Death Valley is both much hotter and much drier than any of these places. It is not that its maximum is so much greater or the diurnal range more severe, but it is more consistently hot than the others. In the others can probably be seen about the best that the sun and drought can do unaided; in Death Valley these are aided by the peculiar topography, and the difference is very appreciable.

It may be of interest to note that the highest maximum observed in the meteorological service of India* was 123°.1, at Pachpadra in Rajputana on May 25, 1886, the same day as the record of maximum at Jacobabad.

A good measure of the rigor of a climate is to be found in the mean daily range of temperature. Where it is small the climate may be hot or cold, but can be endured with much less danger than where this range is large. To ascertain the position of Death Valley in this regard its mean daily range for the months is tabulated with those of other places which can be characterized as of a mild or rigorous climate.

* Blandford, "Climates and Weather of India," 1889, p. 133.

Mean daily ranges of temperature.

Stations.	May.	June.	July.	Aug.	Sept.	Average.
	°	°	°	°	°	°
Galveston, Tex.[1]	6.8	6.4	6.6	6.5	6.3	6.5
San Diego, Cal.[1]	9.8	9.4	9.5	9.9	10.5	9.8
San Francisco, Cal.[1]	9.4	9.5	10.5	10.4	10.3	10.0
New York City, N. Y.[1]	11.2	11.5	11.0	10.2	10.0	10.8
Washington, D. C.[1]	15.2	14.7	14.4	14.8	14.8	14.8
Santa Fé, N. Mex.[1]	21.6	22.0	20.2	18.2	21.4	20.7
Death Valley, Cal.[3]	21.9	23.3	24.6	27.1	22.2	23.6
Yuma, Ariz.[1]	27.6	28.3	24.0	24.2	24.8	25.8
Winnemucca, Nev.[1]	25.1	25.8	29.3	33.8	31.2	29.0
Hyderabad, India[2]	28.0	22.0	19.0	17.0	20.0	20.8
Jacobabad, India[2]	32.0	28.0	24.0	22.0	25.0	26.2
Mooltan, India[2]	28.0	25.0	20.0	18.0	22.0	22.6
Dera Ismail Khan, India[2]	27.0	27.0	21.0	20.0	25.5	24.0
Leh, India[2]	27.0	30.0	29.0	30.0	30.0	29.2

[1] Taken from Greely's "Mean Temperatures and their Corrections in the United States," 1891, pp. III and IV.

[2] Taken from Blandford's "Climates and Weather of India," 1889, pp. 291, 302, and 303.

[3] From Table VII at the end of this bulletin.

Leh is in Eastern Cashmere in the Himalayas, at a height of 11,503 feet. Comparison shows that while the diurnal ranges of temperature are great in Death Valley, they are equaled and surpassed elsewhere.

IV.—THE WEATHER IN THE VALLEY.

The succession of pentad or five-day means (Table VI) gives an easy bird's-eye view of the progress of the elements in the valley. The novel feature which is brought to light is that the pressure is not in this case the key to the conditions of the weather. As it happens the hottest period (July 15 to 24, when the mean temperature was 106°.7) was the time of nearer mean than low barometer, and the same is true of the next hottest term, August 19 to September 2, when the mean temperature was 103°.1. The coolest period was when the barometer was again about mean (May 31 to June 4, temperature 79°.3). In the same way the wind velocities show no relation to the changes of the barometer. Rain came generally with a high barometer, and the humidity is sensitive to nothing but the rain, so that we have the paradox of greatest relative humidity with maximum pressure.

It will now be interesting to follow the note-books of the observer through his five months' task, noting the phenomena of interest.

Rain storms.—May 13, heavy masses of cumulo-stratus clouds moved rapidly from the south all day. A thunderstorm passed up the valley, seeming to draw from the Panamint to the Funeral range. Rain fell on both ranges, but none in the valley. The thunder was first heard at 2.33 p. m., last at 5.33 p. m. The temperature fell 9°. The wind had been in the south, but at 5.43 it changed to the north and increased gradually in violence until at 7.48 it reached a velocity of 37 miles per hour. This is the familiar summer or heat thunderstorm, common in mountainous regions in hot weather. Similar storms were

described on June 13, July 25 and 27, and August 16. All caused a change of wind and fall of barometer. They were always late afternoon or early morning phenomena. Distant thunder and lightning were often recorded when no thunderstorm was seen from the station, and such storms when they came did not always bring rain to the station.

The thunderstorm of July 25 presented some features of especial interest. In the afternoon large masses of thunderheads were seen moving from the southwest and west until darkness set in. The lightning was very vivid, and rain fell to the depth of .04 of an inch. The wind changed from northwest to east, and the temperature fell from 110° to 92°. With this storm came on suddenly a violent wind which unroofed a small adobe building near the station. The roof was thrown about 15 yards westward, and the boards and shingles scattered to the north and west of it. This was apparently a regular whirl, as the wind was previously from the northwest.

The thunderstorm of August 16 gave the heaviest rain of all (0.54 inch). It was a morning thunderstorm, following several days of distant thunder and threatening weather, and it continued only two hours (from 2 to 4 a. m.). The most of the rain (0.51 inch) fell within half an hour. The rainfall on the west side of the valley must have been much larger, as the sound of the water was distinctly heard as it rushed down the cañons six miles distant. Large streams of water also came down on the east side, but no damage was done. The ground became exceedingly soft about the station, and traveling was made dangerous.

The thunderstorm of July 27 caused a fall of 20° in temperature, from 107° to 87°. The rainfall was slight, but the drops were very large and very cold.

Another source of rain was that of the slight showers which occurred on May 31, June 3, and other days. No mention of thunder or lightning is made, and the showers were scattered. The clouds were cumulo-stratus. These are the light cumulus showers of summer.

In all cases the rain was from local storms. There is no evidence of rain from a general storm, and indeed such rain is improbable in this part of the world at this season of the year.

Sand storms were observed several times. On June 29, at 6 p. m., after light westerly winds all day, such a storm came down from Mesquite Valley and passed southward on the west side of Death Valley. The mountains on the west side were entirely obscured, while a dead calm prevailed at the station on the east side until 7.30 p. m., when a high wind set in from the west. Another appeared at 7 p. m. on July 28 and took the same course. It disappeared at 8 p. m., but a thunderstorm was heard and lightning seen to the south until after midnight. Sand storms of the same character were reported on September 22 and 30.

On August 13 the observer had a sand storm at his own station, that is, on the east side of the valley, the preceding having been on the west side. The wind blew a gale, beginning at 5.40 p. m., and for the first half hour the air was filled with sand and dust. The wind subsided at 8 p. m. A similar gale occurred on September 3. The sand storms on the east side seem to have been nothing but gales, which were, for some reason, unusually loaded with sand.

Gales were common during the entire residence in the valley. They were generally from the south and came on every three or four days. they were distinctly diurnal in their character, rarely lasting more than seven hours, and usually only two or three, and dying out toward midnight. The velocity was usually above 30 miles per hour, some reaching 45 miles or more, and one 51 miles per hour. They usually began suddenly and died out gradually. More than half of them were from the south, and four-fifths were from southern points of the compass.

Some of the gales from the south were more protracted and so unusually hot as to be specially designated by the observer as "hot winds." One on June 17 began at 10.40 a. m. and lulled at 6 p. m. It was one continuous hot blast, with a maximum temperature of 112°.6. The sky was partly covered with cirrus clouds, until later a dark stratus came down from the northwest.

Another hot wind set in at 1.35 p. m. on August 4 and continued, with lulls, until 11 p. m. of the 5th. The sky was cloudless and the heat intense (maximum 114°). The maximum velocity was 48 miles per hour at 4 p. m. of the 5th. Numerous whirlwinds were formed in the valley during the 5th and had sufficient power to take up loose boards to a considerable height. Other hot winds occurred on August 10, 26, and 29.

V.—THE AUTOMATIC REGISTERS.

The wind, temperature, and air-pressure were continuously registered during the five months that the station was occupied. The registering instruments worked well, were carefully attended, were compared with the standards at frequent intervals, and were reset when necessary. Their corrections, ascertained by the comparison with the standards, have been used in the compilations which follow. These corrections were always small, and there is no indication that the corrected readings do not as accurately as practicable represent the corresponding meteorological elements.

SUDDEN CHANGES ON THE REGISTER SHEETS.

The thermographic sheets present a very interesting and marked peculiarity. From about 10 o'clock in the evening until about sunrise they often show alternate waves of heat and cold. These were usually of from 3° to 5°. They were most common in the hottest weather, when there were often from three to five of them during each night. One of

the strongest was on June 16, and this will serve as a type. At 2.43 a. m., local time, the thermometer was standing at 76°; it then began to rise and reached 83° (a rise of 7°) at 3.10 a. m.; it then fell slowly to 73° (a fall of 10°), which it reached at 4.50 a. m.; then it rose rapidly to 86°, reaching that point at 5.13 a. m. From this point it took up its regular daily progress. The temperature surges with their duration were as follows: A rise of 7° in 27 minutes; a fall of 10° in 100 minutes; a rise of 13° in 23 minutes. Meantime no appreciable change was made on the barographic sheet, and the anemographic sheet shows only a light and very variable wind.

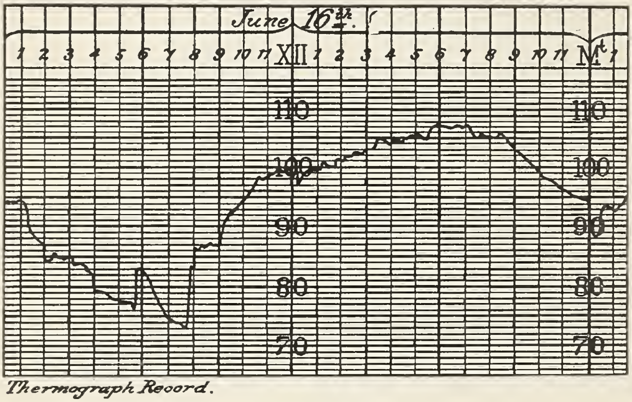

Fig. 6.

The upper part of the daily curve from about 10 a. m. to 4 or 5 p. m. shows a much larger number of minute changes back and forth of a degree or two. While the lower part of the diurnal thermograph tracing has a series of waves, the upper part has a series of ripples.

The waves might have been due to occasional clouds, though the records give no indication of this, and such sudden cloudings and clearings in this place are improbable. Further than this there seems no suggestion to make with regard to the cause of these waves and ripples.

A notable fall of temperature was that late in the evening of July 24. The thermometer was gradually falling, but at 10.33 p. m. it stood at 111°.8. It then began to fall rapidly, and at 11.10 p. m. it had descended to 91°.7, a fall of 20° in 37 minutes. It then rose again rapidly until at 11.23 p. m. it stood at 99°.7, when it resumed its regular diurnal course. In this case there were other changes. The wind, which had been rather sluggish for an hour or more, suddenly increased in velocity until at 10.50 p. m. it traveled at a velocity of 40 miles an hour for a short time. At 11.40 p. m. it again died down to 10 miles per hour. At about 10.35 p. m., also, the barometer began rising rapidly and passed from 30.03 to 30.13, reaching the latter point at 11.12 p. m. It then made a sharp turn and descended about .05 inch in the next hour. The sharp fall in the thermometer, the jump in the barometer, and the

freshening of the wind are all familiar accompaniments of a thunderstorm. On turning to the daily journal of the observer we find the following record, where the hours have been changed to local time: "A thunderstorm began at 10.35 p. m., ended at 11.53 a. m."

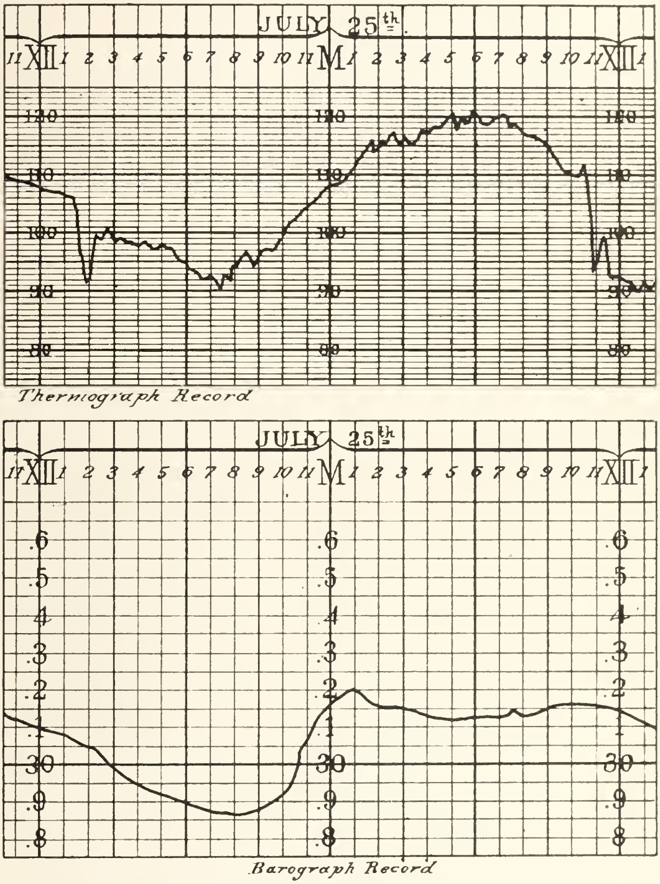

FIG. 7.

The thunderstorm followed by a tornadic storm of July 25 was accompanied by a similar fall of temperature. In this case it fell from 113°.0 at 7.53 p. m. to 92°.4 at 8.10 p. m., or 20°.6 in 17 minutes. It rose again, reaching 99°.2 at 8.33, when it fell again to 92°.5, reaching that point at 9 p. m., local time. According to the journal the violent wind came on at the very moment the sudden fall began, and the maximum velocity was at 8.08, or only two minutes before the end of this fall. The velocity in this case reached 60 miles.

The barographic curve gave a tremendous, but not so rapid, leap, quite unparalleled in magnitude in this record. It was gradually rising, when at 7 p. m. it began to rise rapidly from 29.90. At 9.13 it had reached 30.17, and by 11 p. m. it attained its maximum of 30.20. From

this point it fell slowly for the next twelve hours. In about two hours the mercury rose over a quarter of an inch!

In general the barographic curve is very smooth. The thunderstorms are usually accompanied by a sudden jump, and the pressure remains slightly higher afterwards. Occasionally these jumps occur without any record of thunder, lightning, or rain by the observer. In general, considerable disturbances, relatively, may be shown on one instrument without appearing on the others, or being accompanied by phenomena which attracted the attention of the observer.

HOURLY WIND VELOCITIES.

Table VII gives the average hourly wind velocities. They are in hours of the 75th meridian time; to reduce them to local time, 2 hrs. 47 min. must be subtracted from the hours in column one.

The progress of the velocities through the hours of the day is shown in the curve (Fig. 8) accompanying, plotted on the local hours. It presents several features of interest.

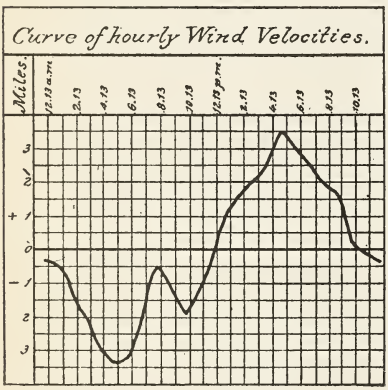

Fig. 8.

In the first place the minimum at about sunrise is more marked than usual. Generally the velocities are approximately equal in the hours after midnight, and it is not easy to fix the time of minimum. In this case the velocities decrease steadily and almost uniformly from the maximum to the minimum, a period of 12 hours.

The principal maximum falls toward sunset. This is much later than is usual. Over the United States generally the local time of maximum wind velocity is 2 p. m. Along the coasts, both Atlantic and Pacific, it falls later, reaching at the two diagonal regions (Washington and Oregon and the south Atlantic coast) an hour as late as 4 p. m. The arid region of the Southwest, from Denver southward and westward, also shows a disposition to delay the principal maximum, but in no case of the regular stations is it later than 4 p. m. In the case of Death Valley this is deferred until 5 p. m.

This retardation of the principal maximum is probably associated with another remarkable feature, and that is the secondary minimum at noon, which is plainly marked in the curve. This is an unusual phenomenon at the regular stations of the United States. At no other station is it so marked, though at half a dozen the velocity does not increase as rapidly at about, or soon after, noon as before or after this time, and in the summer months an actual minimum may be found. Among these stations are Memphis, Abilene, Palestine, Galveston, Yuma, and Red Bluff. At Death Valley this minimum is strongly

marked, and it is not due to individual storms, morning and evening, but appears in each individual month, though it is strongest in June. This peculiarity may be due to the ascensional currents, which change at least some of the horizontal into vertical motion and which must form in this deep and bare valley. Such currents must be unusually strong, and the numerous cumuli and thunderstorms are caused by them. They should be most marked at the time of greatest heat (about 3 p. m.), but their greatest effect in dampening horizontal currents would be earlier, both because when once well started they would develop horizontal currents of their own, and because when well established they would cloud the valley and accelerate the heat maximum. Probably, if there were no ascensional currents in the valley, or if the valley were covered with dense vegetation so as to temper the heat, the curve of wind velocities would be as symmetrical here as is usual elsewhere, and the maximum would fall at 3 or 4 p. m. The establishment of the ascensional currents obliterates this maximum, but permits of one near sunset and another secondary at about 8 a. m. If such is the case the peculiarities of the curve to which reference has been made can all be traced to the character of the valley itself, and should be found in other deep, narrow valleys between bare and steep slopes.

HOURLY TEMPERATURES.

The average hourly temperatures are given in Table VIII. The curve is constructed on the local hours. The minimum falls at about 5 a. m., or near the time of sunrise. The curve rises steadily and rapidly to a maximum at about 3 p. m. It then falls as steadily to the minimum. The steady fall of the temperature during the night, like that of the wind velocities, is remarkable and must be due to the continued radiation to a clear sky from bare rock and sand and to the low relative humidity and dew-point. Dew does not form and the checking of the fall in temperature by the heat given out in the condensation of water does not occur. Eight of the hours (from 11 a. m. to 6 p. m., inclusive) have temperatures steadily above 100° F., and the mean maximum is 105°.5. In only four of the hours does the mean temperature stand below 85°.

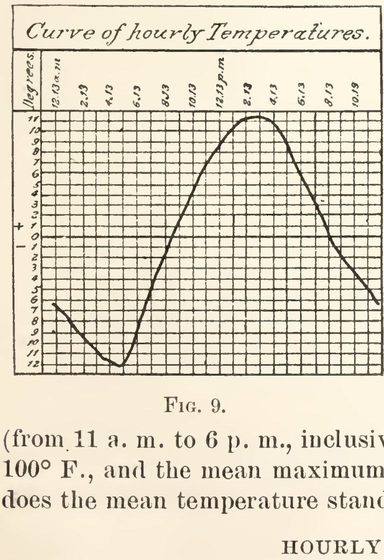

Fig. 9.

HOURLY PRESSURES.

The average hourly atmospheric pressures are given in Table IX. The curve corresponding to this table has been constructed on local hours.

It is a remarkable curve for diurnal pressure, in that the range is very great and there is only a single and well-marked maximum and minimum. It bears a strong resemblance to the temperature curve reversed, except that its maximum is three hours later than the minimum temperatures and its minimum two hours later than the maximum of temperatures.

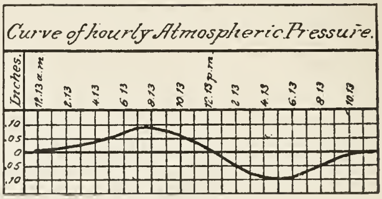

FIG. 10.

This at once suggests that this peculiar curve may be an illusory one, due not to the actual changes of daily pressure, but to some imperfection of the instrument whereby it described not a pressure curve, but a temperature one. The recording instrument was set with the mercurial barometer, corrected for temperature, at midnight April 30, when the observations began, and was compared twice daily (at the regular hours of observation). The readings show that it ran very evenly with the mercurial ones. As it happens, one of these readings was near the time of daily minimum of temperature (5.13 a. m.), while the other was near the maximum (5.13 p. m.). A systematic error in the barograph, due to over-compensation, is much less probable when the observations are checked at these hours than it would be at any others. But the best reason for thinking that this remarkable curve represents the actual change in pressure is to be found in the fact that similar curves have been obtained elsewhere.

The ordinary curve of daily pressure has two maxima and two minima which are fairly constant in time of occurrence, but very various in relative size. In the curve for Death Valley one of these has apparently disappeared, leaving a one-maximum curve instead of a two-maximum one. This seems to be the most striking example of this character which has yet been published, but it is not unique. It is a summer form, and belongs to the interior of great continents, especially to those stations which are both hot and dry. On the North American continent it is found from the Sierra Nevada and Cascades to the eastern slope of the Rocky Mountains and from the Mexican boundary to Fort Rae on Great Slave Lake. It probably extends into Mexico, but does not reach the city of Mexico, as the double maximum type is well marked there. It is also found on the Old Continent from Leh in Cashmere and Nertchinsk to Klagenfurth and Bucharest.

The use of the harmonic analysis in the study of the diurnal curve has shown the cause of its numerous variations. It appears that the actual curve is the resultant of the interference of at least two distinct periodic motions, one with a period of 12 hours, and the other with a period of 24.

The first, or semi-diurnal, is the one commonly recognized. It is the most regular and the most general. Its amplitudes are greatest at the equator and decrease with increase of latitude until they disap-

pear in high latitudes. The phases come on with great regularity in the local hours. It is a phenomenon of a general character and is often considered tidal.

The second, or diurnal curve, is less generally recognized, and the credit of having brought its distinctive features into plain view belongs to Doctor Hann.* It is nearly independent of latitude and altitude, but very sensitive to local conditions. The time of maximum is curiously constant. Out of 85 cases, scattered all over the world, in 35 the maximum fell between 4 a. m. and 6 a. m., and in 26 others it fell between 6 a. m. and 8 a. m. In 71 per cent. of all cases in which it appeared, and in all the remarkable cases, the maximum was between 4 a. m. and 8 a. m. In many of the others the smallness of the amplitude probably prevented exactness in the determination of the maximum.

The amplitude, or half-range, of this curve is very various. It is smallest at coast stations in high latitudes where the coasts are flat. In lower latitudes the coast stations have larger amplitudes, and it is appreciable even on the open sea. It is, however, greatest in valleys between mountains.

The station at Furnace Creek was in a valley of this sort, and the harmonic analysis, when applied to its records, shows that there is here a very clear and noteworthy case of a one-maximum curve of daily pressure. The resulting amplitude is 0.082 inch (or range of 0.164 inch). This amplitude is 2.1 millimetres, and it is worthy of note that the largest amplitude for these curves found by Dr. Hann was barely one millimetre, or less than half that of the curve in Death Valley. The latter was found at Cordoba, Argentina. The largest amplitudes given by Dr. Hann can be compared with that at Furnace Creek in the following statement, to which are added Yuma and Boston for comparison.

Amplitudes of single-maximum curves.

	Inch.
Death Valley (May–September, 1891)	0.082
Yuma (May–September, 1891)	0.045
Cordoba (5 years)	0.039
Bozen, Tyrol (2 years)	0.037
Yarkand (9 months)	0.035
Leh (short series)	0.034
Angola (2 months)	0.034
Mexico (3 years)	0.030
Boston (May–September, 1891)	0.017

The amplitude of the one-maximum curve is apparently larger in summer than in winter, and hence, if deduced for a year, those for Death Valley, Mexico, and Boston, as given above, would be somewhat decreased.

The local time of this maximum at Furnace Creek, as given by the analysis, was 6.05 a. m. At Yuma it was 5.15 a. m.

* "Untersuchungen über die tägliche Oscillation des Barometers," 1889, pp. 13–16.

The semi-diurnal period is not easy to trace in the curve from the average of the observations, yet it can occasionally be detected on the barographic sheets. The analysis shows it distinctly and gives it an amplitude of 0.025 inch. The amplitude for the same months for Yuma was 0.023 inch, for San Diego, 0.015, and for Boston, 0.016. It is interesting to note that the amplitude for the one-maximum curve at San Diego for these months was only 0.001 inch.

VI.—CONCLUSIONS.

The principal features of popular interest in Death Valley are its excessive heat and dryness. The temperature rises occasionally in the shade to 122°; rarely falls at any time in the 5 hot months below 70°; and averages 94°. It is not only hot in summer but consistently hot, and the heat is increased by occasional hot blasts from the desert to the south. The air is not stagnant but in unusually active motion. Gales of a few hours duration are very common, and sometimes they produce sand whirls and sand storms. The heat and movement of the air together make this a very dry—an arid place—and this aridity in summer is almost as consistent as the heat. Rains may fall frequently in the mountains and occasionally in the valley, clouds are by no means lacking, and water can probably always be found at the depth of a few feet in the soil, yet the heat and wind together keep the surface very dry and the relative humidity low. Animal and plant forms are comparatively few, and the former are usually nocturnal to avoid the heat.

Both heat and aridity are increased by the character of the valley. It is narrow and deep, apparently the bed of an old sea, inclosed by high and bare mountains. The white and shifting sands become much heated under the noonday sun; the rest of the surface is in part salt and alkali, in part pebbly wash from the mountains, in part a loose, spongy earth, over which it is difficult to move. With the exception of a few springs, the water is bitter and unwholesome.

The effects of the extreme heat and aridity actually recorded, under conditions which afford full grounds for confidence, must be very serious, but tradition and common report add to these terrors others which are possible enough to deserve quotation.* It is said that the thermometer in the shade has sometimes reached 130°, and once touched 137°. Men exposed to the sun's rays in summer are said to be not infrequently driven insane, and the story is told of one man driving in on a load of borax who died suddenly with the water canteen in his hand. Meat slaughtered at night and cooked is spoiled the next morning; cut thin and dipped in brine it cures in the sun in an hour. A writing desk curled, split, and fell to pieces. Tables warp into curious shapes; chairs fall apart; water barrels, incautiously

*These statements are for the most part from a long and interesting illustrated article in the New York *Sun* for February 21, 1892, signed by John R. Spears.

left empty, soon lose their hoops. But the most terrifying aspect of nature in the valley is reported in the cloud-bursts—a striking and not infrequent phenomenon over the dry Southwest, for which the conditions here are especially favorable. They are small and concentrated storms of the utmost fury, which gather suddenly about the mountains in the hottest weather. An ominous cloud forms with great speed, grows black and full of lightning, sags down to the mountains and releases a flood of water. The tales of the height of the resulting wave of water which comes down the cañon are so marvelous that they border on the mythical and need not be quoted.

The meteorological features of interest lie for the most part in those modifications of diurnal changes which are due to the topography. The range of temperature is unusually great; the hourly progress of the winds show curious changes in speed, in direction, and in temperature. The diurnal change in the barometer is the most characteristic of the form found in continental valleys. It is of the purest single-maximum type and has the largest amplitude known. With these features go those sharp thunderstorms limited to certain hours of the day, and daily gales and hot blasts.

It is also noteworthy that the absolute humidity here is fairly constant and is that belonging to that part of the world. The air in the valley is part of the general aërial ocean and this shows no sharp contrasts in its moisture contents, except where wind prevails across a mountain ridge. Here the prevailing winds are up and down the valley and its relative aridity is due to its higher temperature.

A few words may be given to the winter climate, concerning which there are no recorded observations. The physical conditions of the valley, however, supported by the statements of those who have prospected there in the winter, and of those who have resided there in connection with borax works, enables us to reach a fair idea of this season. For five years, beginning in 1883, about 40 men were employed there. The season began with September and ended in June. By them the climate was considered healthy. Ducks and other migrating birds, jack rabbits, and cottontails were reported as abundant, and the neighboring Piutes extended their migrations into the valley. Snowfalls occurred on the mountains, sometimes to the depth of several feet. Ice forms in, and extreme cold has been reported from, the neighboring, but higher, valleys. In fact the relatively clear sky and bare soil make this region a favorable spot for the fall of winter temperatures. At Yuma the lowest temperature often reaches 27°, and once descended to 22°.5.

In short, following the year through, and accepting the guidance of the observations, of the physical conditions, and of the reports of those who have lived there, it is safe to conclude that the winter must be cool and salubrious, with an inch or two of rain. The early spring and late autumn must be of moderate temperature, with clear delight-

ful air and little rain; the autumn very dry; the summer, with May and September, as we know, hot and arid. While the diurnal changes are great, the annual must be very much greater. The winter mean temperature may be between 35° and 40°, and that of the year 58° or 60°.

TABLE I.—*Highest, lowest, range, and mean daily atmospheric pressure at Furnace Creek, Death Valley, Cal., from May 1 to September 30, 1891.*

Day of month.	May.				June.				July.				August.				September.			
	Max.	Min.	Range.	Mean.	Max.	Min.	Range.	Mean.	Max.	Min.	Range.	Mean.	Max.	Min.	Range.	Mean.	Max.	Min.	Range.	Mean.
	Inches.	*Inches.*	*Inch.*	*Inches.*	*Inches.*	*Inches.*	*Inch.*	*Inches.*	*Inches.*	*Inches.*	*Inch.*	*Inches.*	*Inches.*	*Inches.*	*Inch.*	*Inches.*	*Inches.*	*Inches.*	*Inch.*	*Inches.*
1	30.12	29.84	.28	29.99	30.00	29.78	.22	29.89	29.98	29.78	.20	29.88	29.99	29.84	.15	29.92	29.99	29.81	.18	29.90
2	29.93	29.85	.18	29.86	29.96	29.78	.18	29.89	29.93	29.75	.18	29.85	30.06	29.89	.17	29.98	30.01	29.81	.20	29.91
3	30.02	29.83	.19	29.91	30.13	29.87	.26	30.07	29.92	29.71	.21	29.82	30.05	29.80	.25	29.94	30.03	29.82	.21	29.92
4	30.10	29.89	.21	29.98	**30.23**	30.06	.17	**30.15**	29.93	29.77	.16	29.85	29.98	29.76	.22	29.88	30.02	29.87	.15	29.95
5	30.06	29.86	.20	29.96	30.18	29.93	.25	30.07	29.97	29.80	.17	29.89	29.92	**29.72**	.20	29.83	30.23	29.97	.26	30.10
6	30.03	29.83	.20	29.94	29.99	29.73	.26	29.88	29.92	**29.69**	.23	29.82	30.04	29.84	.20	29.94	**30.29**	30.11	.18	30.20
7	30.01	29.87	.14	29.94	29.92	29.68	.24	29.82	29.90	29.74	.16	29.81	30.08	29.88	.20	29.99	30.19	29.97	.22	30.09
8	30.13	29.96	.17	30.04	29.84	**29.59**	.25	29.74	29.99	29.80	.19	29.90	30.07	29.83	.24	29.96	30.11	29.95	.16	30.03
9	30.11	29.96	.15	30.03	29.95	29.73	.22	29.84	30.07	29.85	.22	29.96	30.02	29.80	.22	29.91	30.09	29.85	.24	29.98
10	30.11	29.94	.17	30.03	29.91	29.70	.21	29.82	30.03	29.71	.32	29.90	29.98	29.82	.16	29.90	30.01	29.82	.19	29.93
11	30.07	29.93	.14	30.00	29.91	29.71	.20	29.80	30.00	29.80	.20	29.89	30.12	29.91	.21	30.01	30.11	29.89	.22	30.01
12	30.11	29.89	.22	30.01	29.91	29.65	.26	29.75	30.06	29.90	.16	29.97	30.10	29.87	.23	30.00	30.08	29.88	.20	29.98
13	30.03	29.87	.16	29.95	29.84	29.71	.13	29.79	30.06	29.85	.21	29.96	30.05	29.89	.16	29.98	30.08	29.87	.21	29.98
14	30.16	30.02	.14	30.09	29.96	29.80	.16	29.89	30.04	29.85	.19	29.95	30.10	29.88	.22	30.01	30.10	29.91	.19	30.01
15	30.23	30.03	.20	30.12	30.14	29.98	.16	30.05	30.02	29.80	.22	29.91	30.10	29.89	.21	30.00	30.06	29.85	.21	29.98
16	30.15	29.96	.19	30.07	30.13	29.91	.22	30.03	30.01	29.82	.19	29.92	30.20	29.98	.22	30.09	30.21	30.02	.19	30.12
17	30.15	29.95	.20	30.05	29.96	29.69	.27	29.85	30.01	29.85	.16	29.94	**30.21**	29.98	.23	30.10	30.24	30.10	.14	30.16
18	30.06	29.93	.13	29.99	29.79	29.64	.15	29.73	30.00	29.81	.19	29.93	30.03	29.83	.20	29.96	30.20	29.98	.22	30.10
19	29.98	29.77	.21	29.90	29.87	29.60	.27	29.75	30.01	29.77	.24	29.91	30.00	29.84	.16	29.92	30.09	29.84	.25	29.98
20	29.92	**29.59**	.33	29.81	30.05	29.73	.32	29.93	29.99	29.80	.19	29.90	30.15	29.94	.21	30.04	30.03	29.90	.13	29.95
21	30.14	29.87	.26	30.06	30.06	29.72	.34	29.92	30.02	29.79	.23	29.90	30.13	29.93	.20	30.04	30.13	29.94	.19	30.03
22	**30.30**	30.11	.19	30.20	29.82	29.65	.17	29.76	30.00	29.82	.18	29.92	30.13	29.90	.23	30.01	30.05	29.86	.19	29.98
23	30.18	30.01	.17	30.11	29.99	29.79	.20	29.88	30.02	29.80	.22	29.93	30.08	29.82	.26	29.96	30.18	29.98	.20	30.09
24	30.15	29.96	.19	30.07	29.93	29.65	.28	29.82	30.05	29.90	.15	29.97	29.95	29.73	.22	29.85	30.25	30.01	.24	30.15
25	30.11	29.89	.22	30.03	29.90	29.71	.19	29.79	30.17	29.87	.30	30.03	29.91	29.76	.15	29.82	30.22	30.03	.19	30.15
26	30.03	29.84	.19	29.94	30.08	29.86	.22	29.99	**30.20**	29.95	.25	30.07	30.01	29.85	.16	29.93	30.28	30.06	.22	30.17
27	30.08	29.92	.16	29.99	30.12	29.92	.20	30.02	30.12	29.79	.33	30.00	30.10	29.87	.23	29.99	30.23	29.98	.25	30.12
28	30.06	29.87	.19	29.98	30.07	29.81	.26	29.95	30.10	29.81	.29	29.97	30.06	29.80	.26	29.95	30.21	29.95	.26	30.08
29	30.11	29.92	.19	30.02	30.00	29.79	.21	29.90	30.00	29.80	.20	29.92	30.05	29.85	.20	29.94	30.02	29.48	.54	29.81
30	30.06	29.88	.28	29.94	30.00	29.81	.19	29.90	30.02	29.79	.23	29.91	30.05	29.87	.18	29.95	29.94	**29.41**	.53	29.68
31	29.94	29.83	.11	29.88	....	....	....	....	29.92	29.78	.14	29.86	30.05	29.85	.20	29.95	....	....	....	....
Average	30.08	29.89	.19	30.00	29.99	29.77	.22	29.89	30.02	29.80	.22	29.92	30.06	29.85	.21	29.96	30.12	29.90	.22	30.02

NOTE.—The values given above were obtained from a Richard's barograph, checked daily by comparison with a standard mercurial barometer. The barograph was set to agree with the readings of the mercurial instrument, corrected for instrumental error and reduced to 32° F. The barograph was compensated for temperature. No corrections for elevation have been applied. The "mean" is from the 24 hourly readings.

TABLE II.—*Daily extremes, range, and mean temperature at Furnace Creek, Death Valley, Cal., from May 1 to September 30, 1891.*

Day of month.	May.				June.				July.				August.				September.			
	Max.	Min.	Range.	Mean.	Max.	Min.	Range.	Mean.	Max.	Min.	Range.	Mean.	Max.	Min.	Range.	Mean.	Max.	Min.	Range.	Mean.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1	106	70	36	89.0	89	**60**	29	**75.5**	**122**	89	33	106.5	116	83	33	103.2	118	81	37	102.3
2	104	79	25	89.5	90	66	24	78.5	**122**	92	30	108.0	118	82	36	103.6	**119**	81	38	103.4
3	99	70	29	87.7	90	69	21	79.1	120	91	29	104.8	119	84	35	104.5	116	85	31	**106.2**
4	102	77	25	90.8	100	66	34	85.2	118	91	27	105.1	118	87	31	103.4	115	92	23	103.8
5	**105**	78	27	92.4	106	72	34	91.3	116	95	21	105.7	114	89	25	100.8	110	88	22	98.0
6	**105**	79	26	**93.4**	111	78	33	97.2	114	89	25	101.7	109	78	31	94.5	100	78	22	89.1
7	96	76	20	85.5	111	85	26	97.5	109	84	25	96.8	108	74	34	93.1	112	82	30	97.1
8	94	62	32	79.5	109	83	26	94.6	109	76	33	92.8	113	**73**	40	93.3	112	86	26	98.3
9	98	70	28	85.5	102	79	23	91.6	106	82	24	93.4	117	77	40	100.0	115	85	30	100.8
10	101	64	37	86.0	106	70	36	91.5	109	81	28	94.0	118	77	41	103.3	111	88	23	98.8
11	100	75	25	89.1	104	82	22	90.7	106	84	22	94.5	114	92	22	102.3	105	75	30	91.9
12	96	78	18	86.8	101	73	28	86.7	109	81	28	97.2	115	93	22	104.1	107	82	25	93.8
13	88	71	17	81.0	94	72	22	80.8	114	**72**	42	96.3	113	96	17	102.9	105	81	24	92.8
14	85	61	24	74.5	96	68	28	83.6	116	82	34	101.6	113	85	28	99.3	103	79	24	90.1
15	94	61	33	81.1	103	78	25	91.2	118	81	37	102.7	110	91	19	100.0	100	75	25	84.9
16	101	67	34	86.8	108	73	35	93.7	119	92	27	105.9	102	79	23	**90.8**	89	68	21	**77.6**
17	100	73	27	88.7	113	84	29	98.8	120	88	32	105.7	104	75	29	89.2	96	70	26	82.3
18	103	68	35	88.9	106	82	24	94.2	120	99	21	108.6	108	83	25	96.0	99	66	33	84.9
19	103	79	24	90.9	104	77	27	91.4	120	94	26	106.5	111	86	25	99.0	103	75	28	89.3
20	98	79	19	86.2	105	81	24	92.0	119	88	31	106.5	110	77	33	97.2	99	79	20	88.2
21	78	**54**	24	**69.4**	113	69	44	94.0	121	88	33	106.4	117	75	42	99.0	98	72	26	84.9
22	90	59	31	75.9	110	84	26	97.2	119	96	23	107.7	120	80	40	102.7	97	74	23	85.1
23	95	70	25	83.0	104	80	24	92.9	120	88	32	107.8	120	82	38	104.0	98	70	28	85.3
24	97	72	25	84.9	109	75	34	93.3	121	95	26	**109.1**	**122**	85	37	105.1	97	76	21	84.9
25	100	71	29	87.0	105	83	22	94.8	121	91	30	105.6	**122**	87	35	**106.4**	95	72	23	82.1
26	101	78	23	90.7	105	82	23	93.6	115	88	27	100.0	121	89	32	104.8	97	**58**	39	79.5
27	99	73	26	85.0	112	77	35	95.8	112	85	27	94.7	119	88	31	105.2	100	59	41	80.9
28	95	70	25	81.6	119	79	40	100.8	107	79	28	**92.7**	117	83	34	104.4	103	67	36	84.3
29	92	59	33	76.8	121	89	32	**108.2**	112	84	28	99.2	117	87	30	104.7	106	65	41	87.2
30	94	69	25	80.0	**122**	96	26	108.0	114	87	27	102.5	118	86	32	104.7	82	72	10	78.8
31	92	67	25	78.4	......	......	......	....	116	80	36	102.3	120	81	39	103.5	......	......	......	....
Average	97	70	27	84.7	106	77	29	92.1	116	87	29	102.1	115	83	32	100.8	104	76	28	90.2

NOTE.—The daily extremes given above are the readings of standard self-registering maximum and minimum thermometers, such as are used at all Weather Bureau stations. The "range" is the difference between the highest and lowest temperatures registered. The "mean" is from the 24-hourly readings of a Richard's thermograph, checked daily by comparison with standard mercurial instruments. The thermometers were exposed in a "sod" shelter 6 feet above ground.

TABLE III.—*Relative humidity at Furnace Creek, Death Valley, Cal., at 8 a. m. and 8 p. m., 75th meridian time, from May 1 to September 30, 1891.*

Day of month.	May.		June.		July.		August.		September.	
	8 a. m.	8 p. m.	8 a. m.	8 p. m.	8 a. m.	8 p. m.	8 a. m.	8 p. m.	8 a. m.	8 p. m.
	Pr. cent.	*Pr. cent.*	*Pr. cent.*	*Pr. cent.*	*Pr. cent.*	*Pr. cent.*	*Pr. cent.*	*Pr. cent.*	*Pr. cent.*	*Pr. cent.*
1	22	7	45	19	28	10	21	7	26	12
2	38	9	35	26	18	12	28	7	32	16
3	25	12	48	24	24	9	22	10	30	17
4	23	13	48	16	23	14	18	5	29	21
5	17	11	34	15	19	12	15	5	37	46
6	9	9	22	13	20	9	16	13	74	38
7	31	12	26	14	17	9	18	6	64	23
8	38	14	28	11	38	13	20	8	41	24
9	20	13	20	12	23	13	20	12	40	18
10	33	13	18	11	27	15	28	17	31	15
11	30	17	23	18	31	16	40	16	31	18
12	32	18	39	18	18	12	38	18	30	12
13	41	48	34	22	30	11	21	22	20	19
14	53	32	32	18	28	12	47	19	22	10
15	57	23	47	19	22	10	33	21	19	22
16	40	14	22	14	16	10	56	29	42	22
17	29	10	26	10	22	10	75	29	34	21
18	24	11	28	14	16	13	43	22	43	17
19	34	9	22	12	20	10	34	10	30	17
20	43	38	13	10	16	6	22	12	28	14
21	62	31	26	8	13	10	25	11	33	20
22	58	15	17	11	20	13	26	11	37	22
23	36	14	16	10	32	14	32	8	36	21
24	23	21	18	10	22	13	21	11	28	17
25	30	14	22	16	34	13	26	8	23	16
26	24	13	22	13	51	21	18	7	36	18
27	30	14	21	10	50	22	16	8	45	16
28	20	20	29	11	72	23	21	13	31	21
29	55	24	16	9	40	18	33	14	31	36
30	32	39	18	12	20	9	31	12	22	20
31	61	14	....	....	38	8	33	12	....	....
Average	34	18	27	14	27	13	29	13	34	20

NOTE.—The values given above were obtained by the use of the whirled psychrometer in a "sod" shelter, 5 feet above ground; thermometers 6 feet above ground.

TABLE IV.—*Kind, amount, and direction (from) of clouds at Furnace Creek, Death Valley, Cal., May 1 to September 30, 1891.*

Day of month.	May.			June.			July.			August.			September.		
	Kind.	Amt.	Direction from.	Kind.	Amt.	Direction from.	Kind.	Amt.	Direction from.	Kind.	Amt.	Direction from.	Kind.	Amt.	Direction from.
1	cs.	2	calm	0	5	0	ks. k.	6	sw. nw.	0	0	0	0	0	0
2	c., cs.	4	w.	c., s.	0	calm	ks. k.	4	sw. w.	0	0	0	ks.	4	s.
3	0	0	0	nim. ks.	5	s. w.	cs. k.	5	sw., w. nw.	0	0	0	D'se hz., k.	4	s.
4	cs.	0	s.	0	4	0	c., ks.	8	w.	0	0	0	k.	5	sw.
5	0	0	0	cs.	0	w.	ks. k.	7	nw. s.	0	0	0	ks.	8	s., sw.
6	cs.	5	s.	0	1	0	0	0	calm	0	0	0	ks.	8	s.
7	0	0	0	0	0	0	0	0	0	0	0	0	c. s.	6	w. s.
8	0	0	0	cs.	0	sw.	0	0	0	0	0	0	s. ks.	9	sw. nw.
9	0	0	0	Lt. hz., cs.	0	nw.	0	0	0	0	0	0	k.	2	calm
10	cs.	0	s.	cs.	8	w.	0	2	0	ks., k.	5	sw.	k.	1	w.
11	cs., ks.	6	s.	cs., c. ks.	10	w. sw.	0	0	0	Lt. hz.	0	calm	0	0	0
12	k. k.	2	e. s.	ks.	8	sw.	0	0	0	k.	4	sw.	0	0	0
13	ks. cs.	10	sw. s.	ks.	8	nw.	0	0	0	ks., k., cs.	8	sw.	cs.	1	w.
14	ks.	8	w.	k.	6	w., nw.	0	0	0	s.	8	w., s.	0	0	0
15	0	0	0	cs.	6	nw.	0	0	0	k. s.	9	n. s.	ks.	4	s.
16	c. k.	2	w. n.	c.	5	w.	c. s.	1	w. nw.	c., ks.	9	nw.	cs. ks.	6	sw. w.
17	cs.	7	s.	c., kc. s.	5	w. nw.	c.	0	nw.	ks.	8	nw., n.	c. ks.	6	s. n.
18	cs., c.	1	w.	c., kc.	6	nw.	ks.	2	s.	k.	8	w., nw.	0	0	0
19	ks.	8	calm	0	0	0	0	0	0	c.	5	w.	0	0	0
20	ks.	10	se., w.	0	0	0	0	0	0	c.	1	w.	cs.	9	sw.
21	nim., ks.	8	nw.	0	0	0	cs.	5	sw.	0	0	0	0	0	0
22	0	0	0	cs.	0	w.	ks., k.	8	sw.	0	0	0	ks.	1	ne.
23	c.	4	calm	ks.	0	nw.	ks. k.	6	sw. s.	0	0	0	0	0	0
24	ks.	8	n., nw.	s.	4	w.	ks., cs. k.	9	s. sw.	c., ks.	5	w.	0	0	0
25	ks.	5	calm	0	0	0	c., cs., ks.	9	sw.	ks., c., k.	4	nw.	0	0	0
26	c. ks.	5	w. sw.	0	2	0	c., ks. s.	10	w. nw.	s.	0	w.	c.	3	w.

27..........	o	o	o	o	o	o	cs., k., s.	8	nw.	o	o	o	o	o	o
28..........	o	o	o	o	o	o	cs. ks.	5	sw. n.	c. k.	o	w. sw.	o	o	o
29..........	ks., cs.	o	se.	ks.	o	nw.	o	o	o	cs. k.	4	w. n.	o	2	o
30..........	ks.	8	calm	k.	6	nw., w.	o	o	o	k.	o	calm	ks.	6	sw.
31..........	ks.	10	nw.	....	....	....	o	o	o	o	1	o	....	....	....
Averages ..	ks.	3.6	s.	cs.	3.0	w.	ks.	3.1	sw.	k.	2.5	w.	ks.	2.8	s.

NOTE.—The *amount* of clouds given is the average for the day on a scale of 1-10, obtained from *frequent* eye estimates during the day. The *kind* of clouds given are those observed at the a. m. and p. m. observations and any others that called for special notice in the daily journal. Where clouds are reported but no amount is given, the average for the day was less than one-tenth.

TABLE V.—*Direction of the wind at 8 a. m. and 8 p. m., 75th meridian time, and average hourly velocity at Furnace Creek, Death Valley, Cal.*

Day of month.	May.			June.			July.			August.			September.		
	Direction.		Average hourly velocity.	Direction.		Average hourly velocity.	Direction.		Average hourly velocity.	Direction.		Average hourly velocity.	Direction.		Average hourly velocity.
	8 a. m.	8 p. m.		8 a. m.	8 p. m.		8 a. m.	8 p. m.		8 a. m.	8 p. m.		8 a. m.	8 p. m.	
			Miles.			*Miles.*			*Miles.*			*Miles.*			*Miles.*
1	se.	se.	6.9	ne.	n.	7.0	s.	nw.	4.0	ne.	s.	9.2	nw.	s.	4.8
2	s.	s.	12.7	n.	se.	9.0	se.	sw.	6.0	se.	s.	7.7	n.	s.	6.8
3	se.	s.	8.6	se.	sw.	7.0	se.	nw.	10.2	e.	s.	10.9	se.	s.	14.1
4	se.	s.	12.3	s.	sw.	3.0	se.	sw.	5.0	s.	s.	15.6	s.	s.	10.5
5	se.	se.	12.0	se.	s.	4.0	w.	s.	8.4	s.	s.	25.9	nw.	n.	11.0
6	e.	s.	14.3	s.	s.	14.7	s.	s.	15.2	s.	s.	11.4	n.	s.	4.0
7	s.	s.	24.9	se.	s.	14.7	s.	s.	19.7	sw.	s.	6.2	n.	s.	4.8
8	ne.	s.	6.0	se.	s.	14.7	se.	s.	14.2	e.	sw.	4.3	n.	n.	6.4
9	ne.	s.	6.9	nw.	nw.	13.5	se.	s.	12.1	nw.	s.	5.2	se.	s.	11.7
10	se.	w.	4.3	se.	s.	7.0	s.	s.	15.3	w.	s.	15.5	se.	sw.	14.0
11	se.	s.	10.0	se.	sw.	19.2	se.	s.	10.0	s.	s.	13.4	se.	s.	7.3
12	se.	s.	16.6	s.	sw.	15.9	n.	s.	8.3	se.	s.	9.8	s.	s.	15.6
13	s.	s.	21.2	se.	ne.	12.6	ne.	s.	6.0	s.	s.	17.1	s.	s.	23.5
14	s.	s.	7.0	se.	nw.	6.0	s.	se.	5.0	se.	s.	12.4	s.	s.	22.4
15	calm	se.	3.7	ne.	nw.	6.0	s.	s.	6.0	ne.	se.	11.8	s.	s.	21.7
16	sw.	s.	8.0	nw.	sw.	6.0	s.	s.	10.1	se.	s.	15.3	s.	s.	9.8
17	n.	s.	9.0	se.	s.	17.4	nw.	s.	7.6	se.	s.	4.5	n.	n.	7.3
18	s.	s.	6.0	sw.	sw.	15.5	se.	s.	11.3	w.	se.	8.0	ne.	s.	5.0
19	se.	se.	9.0	se.	ne.	13.7	s.	s.	11.9	se.	s.	11.1	n.	s.	9.0
20	se.	se.	16.4	e.	sw.	11.3	s.	s.	9.2	w.	sw.	4.8	s.	s.	17.0
21	n.	nw.	10.0	n.	sw.	10.1	s.	s.	8.0	e.	w.	3.3	s.	s.	13.8
22	se.	s.	5.0	sw.	s.	18.3	ne.	s.	8.0	s.	sw.	3.6	s.	s.	16.8
23	se.	ne.	9.0	n.	w.	10.1	n.	sw.	7.9	calm	s.	4.7	ne.	n.	13.4
24	n.	n.	8.0	s.	s.	11.0	sw.	sw.	7.5	s.	s.	4.6	e.	nw.	13.6
25	n.	se.	6.0	se.	w.	12.0	s.	s.	8.0	se.	s.	6.3	ne.	s.	8.0
26	se.	se.	6.0	n.	nw.	8.0	nw.	s.	9.4	se.	s.	7.0	ne.	s.	3.1
27	s.	se.	8.0	e.	sw.	3.9	se.	s.	8.9	s.	sw.	6.2	n.	sw.	2.3
28	se.	se.	16.3	se.	s.	3.8	se.	se.	6.0	s.	sw.	5.8	s.	s.	2.6
29	e.	se.	8.0	ne.	nw.	8.0	n.	s.	6.0	calm	s.	6.4	s.	s.	8.0
30	e.	e.	5.0	n.	nw.	8.7	se.	s.	7.0	calm	s.	6.4	s.	ne.	24.4
31	se.	n.	6.0	....	....	....	n.	s.	7.0	nw.	s.	4.5	....	....	....
Prevailing direction and average hourly velocity.	se.	s.	9.8	se.	s., sw.	10.5	s.	s.	9.1	s.	s.	8.9	s.	s.	11.1

NOTE.—The anemometer was exposed 2 feet and 7 inches above the gable of roof of building occupied as an office; its approximate height above ground was 22.6 feet. No corrections have been applied to reduce to true velocities.

TABLE VI.—*Five-day means of pressure, temperature, and wind at Furnace Creek, Death Valley, Cal., from May 1 to September 30, 1891.*

Date.	Pressure.	Temperature, degrees F.	Wind, average hourly velocity.	Precipitation, sums.	Relative humidity. 8 a. m.	Relative humidity. 8 p. m.
	Inches.	°	*Miles.*	*Inch.*	%	%
May 1-5	29.94	89.9	10.5	....	25	10
May 6-10	30.00	80.0	11.3	....	26	12
May 11-15	30.03	82.5	11.7	....	43	28
May 16-20	29.96	88.3	9.7	....	34	16
May 21-25	30.09	80.0	7.6	0.14	42	19
May 26-30	29.97	82.8	8.7	....	32	22
May 31-June 4	29.98	79.3	6.4	0.09	47	20
June 5-9	29.87	94.4	12.3	....	26	13
June 10-14	29.81	86.7	12.1	....	29	17
June 15-19	29.88	93.9	11.7	....	29	14
June 20-24	29.86	93.9	12.2	....	18	10
June 25-29	29.93	98.6	7.1	....	22	12
June 30-July 4	29.86	106.5	6.8	....	22	11
July 5-9	29.88	98.1	13.9	....	23	11
July 10-14	29.93	96.7	8.9	....	27	13
July 15-19	29.92	105.9	9.4	....	19	11
July 20-24	29.92	107.5	8.1	....	21	11
July 25-29	30.00	98.4	7.7	0.37	49	19
July 30-August 3	29.92	103.2	8.4	....	26	8
August 4-8	29.92	97.0	12.7	....	18	7
August 9-13	29.96	102.5	12.2	....	29	17
August 14-18	30.03	95.1	10.4	0.60	51	24
August 19-23	29.99	100.4	5.5	....	28	10
August 24-28	29.91	105.2	6.0	....	20	9
August 29-September 2	29.93	103.7	5.8	....	31	13
September 3-7	30.05	98.8	8.9	0.20	47	29
September 8-12	29.99	96.7	11.0	....	35	17
September 13-17	30.05	85.5	16.9	....	27	19
September 18-22	30.01	86.5	12.3	....	34	18
September 23-27	30.14	82.5	8.1	....	34	18
September 28-30	29.86	83.4	11.7	....	28	26
Averages	29.96	94.0	9.9	....	30	16

TABLE VII.—*Average hourly wind movement at Furnace Creek, Death Valley, Cal., from May 1 to September 30, 1891.*

Hours ending—	May.	June.	July.	August.	September.	May to September.
75th meridian time.	*Miles.*	*Miles.*	*Miles.*	*Miles.*	*Miles.*	*Miles.*
Midnight	10.3	12.3	12.0	10.6	12.9	11.6
1 a. m	9.3	9.4	10.8	9.7	11.1	10.1
2 a. m	7.7	9.8	11.0	9.5	11.0	9.8
3 a. m	7.6	10.0	10.3	9.4	10.6	9.6
4 a. m	7.5	10.6	9.7	9.1	9.9	9.4
5 a. m	7.4	10.6	9.1	7.1	8.8	8.6
6 a. m	7.0	9.4	7.7	6.1	8.7	7.8
7 a. m	6.6	8.3	6.2	5.4	7.9	6.9
8 a. m	6.2	8.2	5.7	5.5	7.4	6.6
9 a. m	7.0	9.2	4.6	4.7	7.8	6.7
10 a. m	8.6	10.7	6.5	6.2	8.2	8.0
11 a. m	9.8	11.9	8.3	7.7	9.1	9.4
Noon	9.1	10.2	7.4	7.5	9.4	8.7
1 p. m	8.9	8.0	6.6	7.4	9.1	8.0
2 p. m	10.0	9.2	7.0	7.2	10.4	8.8
3 p. m	11.4	9.8	7.9	8.0	11.3	9.7
4 p. m	12.9	10.4	9.1	9.4	13.3	11.0
5 p. m	13.5	10.5	9.3	10.8	13.8	11.6
6 p. m	13.0	11.1	10.0	11.3	14.6	12.0
7 p. m	13.2	12.0	10.9	12.5	14.5	12.6
8 p. m	13.3	12.7	11.9	13.5	15.6	13.4
9 p. m	12.9	12.2	12.1	12.3	14.9	12.9
10 p. m	11.9	12.2	12.3	11.2	13.7	12.3
11 p. m	10.8	13.7	11.3	10.8	12.5	11.8
Average	9.8	10.5	9.1	8.9	11.1	9.9

TABLE VIII.—*Average hourly temperature at Furnace Creek, Death Valley, Cal., from May 1 to September 30, 1891.*

Hours ending—	May.	June.	July.	August.	September.	May to September.
75th meridian time.	°	°	°	°	°	°
Midnight	84.4	90.9	100.3	99.5	88.9	92.8
1 a. m	82.5	88.5	97.8	97.6	88.7	91.0
2 a. m	81.5	86.5	95.8	96.2	86.5	89.3
3 a. m	79.3	85.3	94.4	94.5	84.9	87.7
4 a. m	77.6	84.2	93.7	92.9	83.6	86.4
5 a. m	76.3	82.7	92.0	91.2	82.5	84.9
6 a. m	74.9	81.3	91.1	89.7	80.9	83.6
7 a. m	73.9	**80.2**	90.0	87.6	79.4	82.2
8 a. m	**73.0**	81.0	**89.3**	**86.7**	**79.3**	**81.9**
9 a. m	75.2	84.0	92.5	89.6	79.5	84.2
10 a. m	78.9	87.5	97.1	94.1	83.4	88.2
11 a. m	82.1	90.4	100.5	98.2	87.5	91.7
Noon	85.1	92.6	103.6	101.3	91.0	94.7
1 p. m	87.7	95.4	106.3	104.7	93.7	97.6
2 p. m	90.4	97.4	108.4	107.7	96.8	100.1
3 p. m	92.5	99.4	111.0	110.1	98.9	102.4
4 p. m	93.8	101.0	112.6	111.9	100.8	104.0
5 p. m	94.6	102.7	113.7	113.0	**101.5**	105.1
6 p. m	**94.9**	103.4	**113.9**	**113.8**	101.4	**105.5**
7 p. m	94.4	**103.5**	113.6	113.6	100.0	105.0
8 p. m	93.6	102.4	112.1	111.4	98.0	103.5
9 p. m	91.3	99.8	109.5	107.8	94.7	100.6
10 p. m	88.9	96.7	105.9	104.2	92.5	97.6
11 p. m	86.6	93.9	103.0	102.1	90.8	95.3
Average	84.7	92.1	102.1	100.8	90.2	94.0
Range	21.9	23.3	24.6	27.1	22.2	23.6

TABLE IX.—*Average hourly atmospheric pressure at Furnace Creek, Death Valley, Cal., from May 1 to September 30, 1891.*

Hours ending—	May.	June.	July.	August.	September.	May to September.
75th meridian time.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Midnight	29.960	29.847	29.889	29.926	29.993	29.923
1 a. m	29.978	29.861	29.906	29.938	30.005	29.938
2 a. m	29.994	29.875	29.924	29.951	30.015	29.952
3 a. m	30.001	29.884	29.928	29.960	30.020	29.959
4 a. m	30.006	29.895	29.936	29.968	30.028	29.967
5 a. m	30.012	29.905	29.942	29.977	30.035	29.974
6 a. m	30.025	29.915	29.952	29.987	30.038	29.983
7 a. m	30.033	29.930	29.967	29.994	30.048	29.994
8 a. m	30.052	29.951	29.972	30.011	30.064	30.010
9 a. m	30.068	29.969	29.993	30.035	30.086	30.030
10 a. m	30.078	29.981	**30.004**	30.050	30.104	30.043
11 a. m	**30.079**	**29.984**	**30.004**	**30.054**	30.108	**30.046**
Noon	30.070	29.972	29.993	30.047	**30.109**	30.038
1 p. m	30.057	29.957	29.979	30.033	30.090	30.023
2 p. m	30.038	29.939	29.963	30.006	30.059	30.001
3 p. m	30.006	29.915	29.931	29.982	30.027	29.972
4 p. m	29.982	29.886	29.902	29.948	29.991	29.942
5 p. m	29.956	29.856	29.868	29.914	29.960	29.911
6 p. m	29.933	29.831	29.842	29.885	29.937	28.886
7 p. m	29.914	29.808	29.818	29.868	29.929	29.867
8 p. m	**29.905**	29.798	**29.813**	**29.862**	**29.924**	**29.860**
9 p. m	29.906	**29.797**	29.819	29.864	29.936	29.864
10 p. m	29.921	29.806	29.833	29.876	29.957	29.879
11 p. m	29.941	29.825	29.861	29.903	29.982	29.902
Average daily	29.996	29.891	29.918	29.960	30.019	29.957
Daily range	0.174	0.187	0.191	0.192	0.185	0.186